



# Supplemental Materials for *La Plata Nature Refuge*

*Assessing Land Change*

An Interactive Qualifying Project  
Submitted to the Faculty of  
WORCESTER POLYTECHNIC INSTITUTE  
In partial fulfillment of the requirements for the  
degree of Bachelor of Science

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Date:  
May 13th, 2021

Submitted to:

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Project Center:  
San Juan, Puerto Rico

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## A. About the sponsor

The Department of Natural and Environmental Resources (DNER) served as the sponsor for our project based at the La Plata Nature Refuge, River and watershed. The DNER is a government administration founded in 1972 (Wikimedia Foundation, 2021) and its mission has evolved to encompass management of Puerto Rico's environmental resources and ecosystems through conservation and protection programs to ensure the environment's longevity for future generations (Ortiz, 2019). The project assessed the effects of climate change on the landscape of the La Plata Nature Refuge, river, and watershed. The project also documents the changes from recent years, and helps plan for changes in the future. This project allows the DNER to continue its mission of conservation for Puerto Rico's future generations by preserving what is left of a climate change infected landscape.

A challenge that the DNER faces as this project develops is the missing information from undocumented changes to the landscape over the years as well as the variability of climate change and its uncertain future. Not surprisingly, the DNER has educational ties to the surrounding Puerto Rico community. The DNER holds educational presentations and activities for students and adults alike about environmental topics related to climate change, natural resources, ecosystems etc. (Imflores, 2021). In connection to La Plata Nature Refuge, the DNER maintains the facility for public recreation use as well as monitors the area for any dangerous conditions to water levels or pollutants.

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- Wikimedia Foundation. (2021, January 25). *Puerto Rico Department of Natural and Environmental Resources*. Wikipedia.  
[https://en.wikipedia.org/wiki/Puerto\\_Rico\\_Department\\_of\\_Natural\\_and\\_Environmental\\_Resources](https://en.wikipedia.org/wiki/Puerto_Rico_Department_of_Natural_and_Environmental_Resources).

## B. Contributions

### Authorship of Report

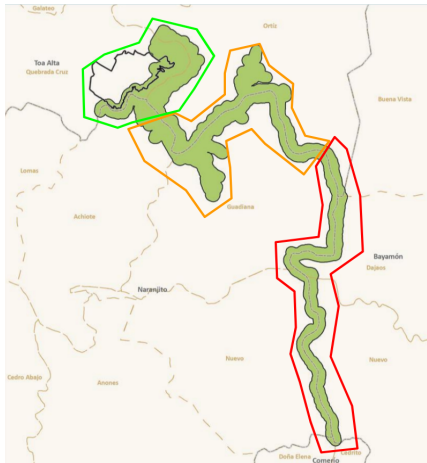
Section	Author	Editors
<b>Abstract</b>	Joe	Adelaide and Heather
<b>Introduction</b>	Joe	Adelaide and Heather
<b>Background</b>	Adelaide, Heather and Joe	Adelaide, Heather and Joe
La Plata Nature Refuge	Adelaide	Heather and Joe
Climate Change as a Threat to Land Change	Heather and Adelaide	Joe
Human Influence on the Climate and Land	Heather and Joe	Adelaide
How Climate Change Affects Land Change	Adelaide and Joe	Heather
Effects of Climate Change on Puerto Rico's Land	Heather, Adelaide, and Joe	Heather, Adelaide, and Joe
Impacts on La Plata Reservoir and River	Adelaide and Heather	Joe
Assessing Land Change	Heather and Joe	Adelaide
<b>Methodology and Results</b>	Heather	Adelaide and Joe
Objective 1: Interviews	Heather	Adelaide and Joe
Climate Change Experts	Heather	Adelaide and Joe
Land Change Expert/Land Manager	Joe and Heather	Adelaide
Public Water Department Employees	Adelaide	Heather and Joe
Objective 2: Timeline of Disaster Events Impacting Puerto Rico	Adelaide	Heather and Joe
Timeline Results	Adelaide	Heather and Joe
Objective 3: Observable Land Change in La Plata River and Reservoir	Heather	Adelaide and Joe



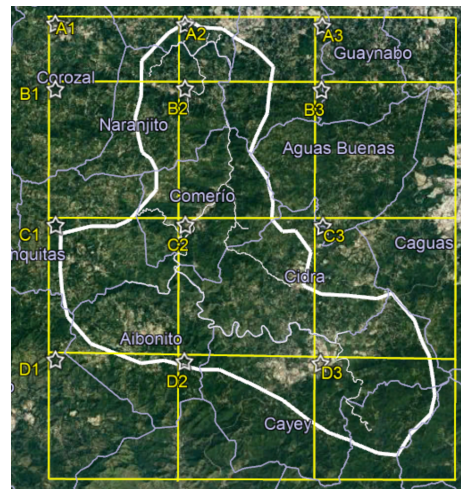
Changes to River and Reservoir: Results	Heather	Adelaide and Joe
Objective 4: Observable Changes of Vegetation and Development in the La Plata Watershed	Heather	Adelaide and Joe
Changes in Vegetation and Development: Results	Adelaide	Heather and Joe
Surveys with La Plata Community Members	Joe	Adelaide and Heather
News and Local Photos	Adelaide	Heather and Joe
News and Local Photos: Results	Adelaide	Heather and Joe
Summary of Results	Heather	Adelaide and Joe
<b>Recommendations and Conclusion</b>	Adelaide	Heather and Joe
Management Recommendations	Adelaide	Heather and Joe
Steps for a Future Project	Heather	Adelaide and Joe
Conclusion	Joe	Adelaide and Heather

## Project Contributions

La Plata Reservoir and River area divided



Watershed (white) and grid (yellow)



Adelaide McFarland

### I. Interviews

#### A. Patrick Gonzalez

- B. Francisco Catalá Míguez
- C. Gene Camargo
- D. Wyatt Arnold
- II. Figures 1, 3, 4, 9, 12, 13, 14, 21, 22, 23, 24, 25, and 34
- III. Tables 1 and 4
- IV. Timeline years
  - A. 2003-2005
  - B. 2012-2014
- V. Satellite Imagery
  - A. Red section of La Plata River area
  - B. Grid sections C1, D1, D2, D3 of the watershed
- VI. Took the lead on designing the final format for the timeline and finding formats that worked for it
- VII. Searched for images in news source of [WAPA.tv](http://WAPA.tv)
- VIII. Literature
  - A. Almodóvar, E. (2015, August 7). *USDA Declares Drought Disaster in Puerto Rico*. USDA Natural Resources Conservation Service Caribbean Area. Retrieved April 14, 2021, from <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/pr/newsroom/releases/?cid=nrcseprd385827>
  - B. Álvarez-Berrios, N. L., & Holupchinski, E. (2017). *Maximum Extent of Drought*. <https://nca2018.globalchange.gov/chapter/20#fig-20-17>.
  - C. Cai, A. (2007, August 5). *Map of the 78 municipalities of Puerto Rico*. Wikimedia. Retrieved March 8, 2021, from [https://commons.wikimedia.org/wiki/File:Map\\_of\\_the\\_78\\_municipalities\\_of\\_Puerto\\_Rico.png](https://commons.wikimedia.org/wiki/File:Map_of_the_78_municipalities_of_Puerto_Rico.png)
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- V. *State of the Climate: Drought for Annual 2015*. (2016, January 13). NOAA National Centers for Environmental Information. Retrieved April 14, 2021, from <https://www.ncdc.noaa.gov/sotc/drought/201513#pr-sect>
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## Heather Lohrey

- I. Interviews
  - A. Patrick Gonzalez
  - B. Gene Camargo
  - C. Jay Lund
  - D. Bill Gould
- II. Figures 2, 5, 6, 7, 8, 10, 11, 15, 16, 17, 18, 19, 20, 27, 28, 29, 33 and 35
- III. Table 2
- IV. Took lead on Slide formatting, Satellite Imagery (Google Earth Pro), ArcGIS prototype, and stage 2 research about modeling (for recommendation)
- V. Timeline years
  - A. 2006 - 2008
  - B. 2015 - 9/7/2017
- VI. Satellite imagery
  - A. Orange section of La Plata River area
  - B. Grid sections C2 and C3 of the watershed
  - C. Coordinates from DNER in A2 - all pins, polygons and paths on file
- VII. Searched for images in news source of [El Nuevo Día](#) and [The San Juan Daily Star](#)
- VIII. Literature
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## Joe MacDonald

- I. Interviews
  - A. Francisco Catalá Míguez
  - B. Wyatt Arnold
  - C. Jay Lund
  - D. Bill Gould
- II. Tables 3 and 5
- III. Timeline years
  - A. 2009-2011
  - B. 9/8/2017-2020
- IV. Satellite Imagery
  - A. Green section of La Plata River area
  - B. Grid Sections A1, A2, B1, B2
- V. Searched for images in news source of [elvocero.com](http://elvocero.com)
- VI. Took the lead on communicating with sponsors for resources such as imagery, community survey data, management plans for La Plata refuge, and scheduling
- VII. Literature
  - A. Damiani, T. (2020, February 7). *NGS Updates Positioning Coordinates after Puerto Rico Earthquake*. NOAA. Retrieved February 18, 2021, from <https://geodesy.noaa.gov/web/news/coordinates-puerto-rico-earthquake.shtml>
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## C. Interviews

Interviews were conducted to collect information about how climate change and weather patterns influence land change and land management plans. The information from these interviews helped us to gather a deeper understanding of the project and give complete answers to how natural disasters are affecting land change at La Plata.

### Interview Request Email

Hello insert name,

We are a group of students from Worcester Polytechnic Institute (WPI) in Massachusetts. For our Global Project, we are remotely conducting research in Puerto Rico to understand how land change can affect drinking water reservoirs, and the rivers that flow into them. We want to understand how climate related natural disasters are influencing landscapes to help with assessments of land change. The information we collect from this research will be shared with the sponsor of our project, the Department of Natural and Environmental Resources (DNER) in Puerto Rico. The information will be shared with employees in the form of a recommendation that we supply for their future management of the La Plata Reservoir.

We are reaching out because we think you could provide helpful insight into our project, with a semi structured interview. This interview is strictly part of our project and will be used to reinforce our own knowledge gathered from reading research articles and talking with our sponsor, the DNER. The results of our research will be published in WPI's database.

**Through this interview we are looking for more information on how you manage water resources for potential impacts from hurricanes, droughts or earthquakes. As well as general management plans or other indicators you look at regularly.\*** The interview should take no more than one hour of your time. Information from this interview will be used in the final report with your name if you so choose. This interview is completely voluntary, and there is no obligation to participate or answer any of the questions we ask you.

If you wish to contact us for more information feel free to email our group alias [gr-ClimateChange\\_PR\\_C21@wpi.edu](mailto:gr-ClimateChange_PR_C21@wpi.edu). Our WPI advisors for this project are Prof. Alex Sphar and Prof. Lorraine Higgins. Thank you in advance for any interest in participating.

We look forward to hearing from you,

**Adelaide McFarland** | Biotechnology

**Heather Lohrey** | Civil Engineering

**Joe MacDonald** | Civil Engineering

\*The sentence written in bold was altered based on the person we were contacting and what field they were an expert in.

### Interview Procedure

1. Introduce team
  - a. Team from WPI exploring land change in puerto rico
2. Read consent form and wait for verbal response
  - a. Information will be shared with our sponsor DNER
  - b. Published in WPI database for student projects
  - c. Completely voluntary
    - i. No obligation to answer each question we ask

- d. Do you agree/consent?
- e. Ask if we can record zoom for later reference
  - i. Ask if we can record name
- 3. Explain project and why we want to speak to them
  - a. La Plata river and reservoir is important as they are sources of drinking water and recreation.
  - b. Assessing land change can help understanding current risks and planning for future change
  - c. understand how these climate related natural disasters are influencing landscapes to help with assessments of land change.
    - i. 2003 to 2021.
  - d. overlaying satellite imagery, in conjunction with first hand observations, throughout the time period being studied.
  - e. Why him
    - i. How climate change is impacting weather patterns
    - ii. How climate change is developing and impacting land change
    - iii. External knowledge from outside Puerto Rico
- 4. Ask if they have any questions on project before we start

## Climate Change Experts

Interviews with climate change experts gave us insight into how climate change is influencing weather patterns and how that can affect land change. The information also solidified the background literature research we had done for the project.

### Patrick Gonzalez

No transcription available - see notes below

Summary Table of key points from the interview.

<p><b>Role/Experience of Interviewee</b></p>	<ul style="list-style-type: none"> <li>● Worked in the field for 28 years</li> <li>● Did PHD research on anthropogenic climate change in Africa</li> <li>● Previously did research in Latin America, US and Africa</li> <li>● Lead author for the IPCC since 2009</li> <li>● Now works at UC Berkeley as an associate professor and with National parks as principal research scientist</li> </ul>
<p><b>Summation of information from Interview</b></p>	<ul style="list-style-type: none"> <li>● Helpful information in:           <ul style="list-style-type: none"> <li>○ <a href="#">US national climate assessment</a> <ul style="list-style-type: none"> <li>■ <a href="#">Chapter on Caribbean</a></li> <li>■ <a href="#">Volume on Climate</a></li> <li>■ <a href="#">Volume on impacts and vulnerability</a></li> </ul> </li> <li>○ <a href="#">Climate Data Online</a></li> <li>○ <a href="#">His 2018 analysis published in environmental research letters</a></li> </ul> </li> <li>● Finding satellite data that is already classified will be the least time consuming for us to look at and understand</li> <li>● Separation of history of climate change and predictions for the future</li> <li>● History:           <ul style="list-style-type: none"> <li>○ Land use and resulting land cover change               <ul style="list-style-type: none"> <li>■ Land use exerts more influence than climate change - on land change</li> </ul> </li> <li>○ Hurricanes are hard to categorize because measurement system has changed over the years</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>● Future: <ul style="list-style-type: none"> <li>○ Most predictions are saying an increase in frequency and size (?) of extreme events</li> <li>○ Emissions models <a href="#">IPCC emissions scenario for future</a></li> <li>○ Take into account changes in: <ul style="list-style-type: none"> <li>■ Populations</li> <li>■ Energy use</li> <li>■ Economic activity <ul style="list-style-type: none"> <li>● Socioeconomics</li> </ul> </li> </ul> </li> </ul> </li> </ul>
<b>Information directly relevant to our project</b>	<ul style="list-style-type: none"> <li>● Puerto Rico average precipitation is decreasing but short periods of intense rainfall are increasing - have more rainfall</li> <li>● Indicators - temp., precipitation, tree mortality, frequency of extreme events, land cover</li> <li>● How to combat climate change - most effective thing to do is change our behaviors as a global society - or behaviors on the island - reduce carbon emissions</li> </ul>

**Notes:**

1. Brief introduction
  - a. How long have you worked in this field?
    - i. 28 years, PhD research on anthropogenic climate change in south africa
    - ii. Applying results of research to natural resource management
  - b. Where do you work?
    - i. UNPS principal research scientist
    - ii. Associate adjunct professor at UC Berkeley
  - c. How long have you been working there?
    - i. Masters in Civil and Environmental from stanford
    - ii. UC Berkeley - 7 years
    - iii. Science to policy - influence change
      1. Worked in DC for a while
  - d. Where else have you worked?
    - i. Conducted research in LA, US, Africa
    - ii. Lead of forest carbon science for NAture Conservancy
    - iii. Lead for climate change science for 10 years for USNPs
    - iv. Government, academia and neither (NGO)
    - v. Highest level - lead author in IPCC since 2009
    - vi. Coordinating lead author for Climate change in the US
  - e. What do you do? Main focus of work?
    - i. Research, assistance, communication
    - ii. All aspect of climate change
    - iii. Applying information for fire management, invasive species control, ecosystem, **communicates results to engage public involvement and contribute to policy solutions**
    - iv. *Have you done any work in Puerto Rico?*
      1. *Never worked in puerto Rico*
2. Additional Information
  - a. For sponsor
    - i. What are the resource management decisions that our work is informing
    - ii. How do they time flow releases from dam
      1. Flood control
    - iii. What is the exact area they need to conserve without any housing development?
      1. Without impervious service
    - iv. What statute governs the land use?
      1. Is it like a state park

- 2. Restriction of development
- v. How do these decisions change under climate change
  - a. Historical observed climate change
    - i. Climate
    - ii. Impacts on ecosystems
    - iii. Impacts on human systems
  - b. Projections of future
- b. Resources
  - i. US national climate assessment
    - 1. Chapter on Caribbean
    - 2. Volume on Climate
    - 3. Volume on impacts and vulnerability
    - 4. Will have past extreme events - Severe storms section of climate chapter
  - ii. His 2018 analysis published in environmental research letters
    - 1. They discuss how climate change is having a stronger impact on national parks than US overall
    - 2. They are seeing larger temperature increases
    - 3. Plants and animals are not able to evolve or adapt as fast as the climate is
  - iii. NOAA weather station data
    - 1. Climate Data Online
    - 2. Search for puerto rico
    - 3. San juan have longer time series
    - 4. Look at it by season
  - iv. Landsat/other satellite data
    - 1. Geo explore portal?
    - 2. Earth explorer?
    - 3. USGS
    - 4. National land cover data set - least time consuming
      - a. Has already been classified
      - b. Grouping by years
    - 5. Ideally go back and get a scene at the same time each year
      - a. Every year is ideal, but every 5 years would work
    - 6. USDA has good aerial photographs but not classified
    - 7. When looking at aerial photos of land easily distinguish between and focus on forest, grassland and urban
    - 8.
- c. History of Climate Change
  - i. Human factors land cover change - urbanization
  - ii. Land use exerts stronger influence than climate change
  - iii. Climate trends
    - 1. Increase in temperature
      - a. Anthropogenic cause
      - b. Emissions cars, power plants, deforestation
      - c. 1.3 degrees per century
    - 2. Precipitation declined but not statistically significant
  - iv. Hurricanes
    - 1. Cannot say if anthropocentric climate change has effect - system to measure hurricane strength changed so data is all related
    - 2. Cat 4 and 5 wind speeds increased
    - 3. Numbers/amount have not changed
    - 4. Runoff
      - a. Frequency of extreme events have increased despite precipitation decrease
      - b. Average would be lower but peak would be higher
    - 5. Vegetation cover
      - a. Shifting vegetation upslope towards equator, towards the pole

- b. Change in temps and rainfall
  - c. Not attributed to climate change in puerto rico
  - d. Tree mortality from heat/ drought and blow down
    - i. Regenerations depends on conditions after blow down
      - 1. Drought or wet
  - e. More vegetation holds the water line in soil
- d. Predictions of Climate Change
- i. [IPCC emissions scenario for future](#) - from 2013 assessment, once on the page - at the bottom there is a download for the full chapter
    - 1. Population, energy use, economic activity
      - a. Set socio economic scenarios for future
  - ii. [Look at his 2018 research](#)
    - 1. 2100 increase in 3 degrees celsius - worst case
    - 2. Lowest case is 1C
  - iii. [National climate assessment](#)
  - iv. Most of it is projecting increases in extreme events
    - 1. Future risk
- e. Indicators
- i. Temp
  - ii. Precipitations
    - 1. Peak runoff
  - iii. Tree mortality
  - iv. Average annual and seasonal
  - v. Frequency of extreme events
  - vi. Land cover
    - 1. Impervious surface
  - vii. Indicator of insects
    - 1. Caribbean national forest PR
    - 2. [Lister and Garcia national academy of sciences](#)
    - 3. Heat killed off insects
    - 4. Analogy with the trees also dying from heat
- f. Behaviors
- i. Avoid risks by reducing carbon emissions and other human sources
    - 1. Systematic global action can help their local situation and ours
  - ii. Avoid drastic changes under climate change
- g. Are they below tropic of cancer
- i. Tropical or subtropical
  - ii. Yes they are just below tropic of cancer = tropical

## Jay Lund

Summary Table of key points from the interview.

<b>Role/Experience of Interviewee</b>	<ul style="list-style-type: none"> <li>● Director of watershed science at UC Davis for 34 years</li> <li>● Worked at University of Washington</li> <li>● Works with water management problems and uses models of physics and chemistry and economics to identify solutions for reservoir operations or land use decisions</li> <li>● Does analysis using historical records and modifies them to match what is being seen in climate change</li> </ul>
<b>Summation of information from Interview</b>	<ul style="list-style-type: none"> <li>● Issues concerning in habitats           <ul style="list-style-type: none"> <li>○ Increase in temperatures</li> <li>○ Change of species</li> <li>○ Aquatic and in forets</li> <li>○ Hydrology and precipitation changes</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ Hurricanes</li> <li>● Information about California <ul style="list-style-type: none"> <li>○ More frequent extreme events</li> <li>○ Lots of droughts</li> </ul> </li> <li>● Variable hydrology between natural and human causes</li> </ul>
<b>Information directly relevant to our project</b>	<ul style="list-style-type: none"> <li>● How to approach bodies of water <ul style="list-style-type: none"> <li>○ Create a schematic of what the system looks like</li> <li>○ Mass balance <ul style="list-style-type: none"> <li>■ Dry wet conditions</li> <li>■ Average Conditions</li> <li>■ Seasonal</li> </ul> </li> </ul> </li> <li>● Figure out people involved <ul style="list-style-type: none"> <li>○ Organizations</li> <li>○ State and local</li> <li>○ Groups of people</li> </ul> </li> </ul>

### Transcription

**Joe:** [describing project]

**Jay Lund:** So the major concern is drinking water quality or are there ecosystems or recreation or other things going on, floods I imagine

**J:** all of the above

**JL:** a general water problem?

**J:** Mostly documentation, they don't have great records of what's going on with the physical land before and after disasters. And how to do a better job of that moving forward because they are obviously going to have to UNCLEAR

**JL:** You'll have to use satellite imagery as much as you can than

**J:** Heather do you want to get into the initial questions then

**Heather:** Yeah so just some brief background questions. I know you are listed as director of Watershed sciences at UC Davis, but how long have you kind of worked in this climate change, watershed, environmental field?

**JL:** About 20 or 30 years

**H:** Quite a bit of time. So you're currently at UC Davis, correct

**JL:** Yes

**H:** And how long have you been with them?

**JL:** Since 1987, so what's that 34 years

**H:** So I guess before UC Davis, where else have you worked in the field or outside of UC Davis?

**JL:** I was a student in the University of Washington so in a sense I have never worked a day in my life.

**H:** With your work at UC Davis and your department there, what do you focus on in research or studies?



**JL:** I focus on water management problems, modeling of those problems. Particularly optimization of management of those problems from economic and environmental perspectives.

**H:** Joe, do you want to pick it up from here?

**JL:** You're on mute Joe

**J:** sorry about that. So one of our questions is, what issues do you find most concerning in habitats? Like coastal habitats, inland, island

**JL:** With climate change?

**J:** Yes

**JL:** I think the temperatures are going to increase, and that by itself will tend to change the kind of species that thrive in the new environment. I'd expect to see some changes in species composition, both aquatic and in the forests. There are also going to be some changes in the hydrology and the precipitation certainly in terms of hurricanes that regions have hurricanes. There have been a lot of people who have been trying to forecast well are the hurricanes going to get more frequent less frequent bigger smaller. I am sure you're going to be talking to somebody that has some expertise in that. And then one of the other things that would worry me is what the population is of the downstream area and worry for floods.

**J:** Ok. What is the biggest effect of climate change you see on weather patterns?

**JL:** I think it's probably the changing of frequency of extreme events. The frequency and the character of extreme events. For this area I think the hurricanes will obviously be important but obviously what happens in the dry seasons. Some of those areas in the Carribean have some pretty pronounced dry season. If those are longer or shorter, more or less frequent, that will become important.

**J:** And since 2003, that's the year we're kind of using as the marker. What are the major changes that you have seen and is it a consistent timeline of natural change or is it majorly skewed by climate change?

**JL:** I don't know anything about Puerto Rico. I don't know any local knowledge.

**J:** No this is for the area you're working on.

**JL:** Oh so in California we certainly see effects of climate change in terms of earlier snow melt. This might be something you also see in Massachusetts. And we seem to have more frequent extreme events. The wettest year in record was in 2017 right after the warmest drought we've ever had. It wasn't the worst drought in terms of precipitation but it was the warmest drought we ever had. And now we're having another drought. On average we might be doing fine, but the extreme events are really exercising the reservoirs and the groundwater basins.

**J:** Can you, did you separate what changes are natural and what are more human caused?

**JL:** Everybody will have a little different assessment of that. California has always had a highly variable hydrology but it appears to be becoming more variable and certainly warmer. So the warming I think is mostly climate change some of the changes in variability is from climate change at least that's what the capitational models say.

**J:** And that's all the questions we have for you. Oh one more question. What are your day to day activities like for water management?

**JL:** I flush the toilet, I take showers, I wash the dishes, I water the lawn sometimes.

**H:** I guess to rephrase there. [Zoom audio difficulties] You had kind of mentioned that you work on water management problems and the modeling of those problems, so can you kind of walk us through what work you do in that and the process in that, and how you go about that, what you see or anything you look for.

**JL:** Yeah I work a lot with students and the students all have masters thesis and dissertations on these different subjects. We have research projects with the state and sometimes federal governments and sometimes other people. We work on different floods, drought, water supply, ecological problems, regional water problems that usually have a mix of floods and droughts in them water quality as well. And we make mathematical models of them with physics, the most important physics and chemistry and economics and some of the regulations and policies. And we try to play with those models and try to find some promising directions for solutions. Better to do experimentation with a computer model than in the real world with real people

**H:** What type of solutions do you guys look for then? What are you trying to solve I guess.?

**JL:** The decisions we recommend are things like reservoir operation policies, water conservation policies, land use decisions for environmental restoration, nitrogen fertilizer policies for agricultural reasons. We look at groundwater contamination in those regions. Things like taxation policies that regard water and agriculture a whole range of things.

**H:** Yeah so when identifying those solutions. I guess you kind of look at any indicators and signs that you're seeing in water resources itself. Or the weather patterns to predict and simulate that future? I guess how do you look at that?

**JL:** Well most of our analysis uses historical records and then sometimes we will modify the historical records, the historical variability, to match a little bit more closely what we're seeing in the climate change projections, climate models.

**H:** A mix of history and future projections to mold and model future solutions to the problem

**JL:** Right, we're never sure what the future is going to be but we have some ideas of what it might be.

**H:** Yeah we can take some guesses possibly

**JL:** I mean every student that's trying to pick a major has the same kind of a problem.

**H:** You don't have to tell us twice. Were both civil engineers so we're kind of stuck in that field,

**JL:** There will always be jobs for you.

**H:** Yes there will always be jobs for us. I mean really quick interviews. There is not a lot of information we need from you. But this has been really helpful. Do you have anything you think would be most important that we look at when looking at water resources or watersheds, or anyone you recommend we speak with? If you don't have anything that's fine as well.

**JL:** I guess when I come to a new basin to work on I try to do three things. First I try to make a schematic of what the system looks like, the rivers, the reservoirs, the towns, the agriculture areas, flood prone areas. It's schematic. You know how it fits on the ground. And then I try to get something of an idea of the mass balance under dry conditions under wet conditions in case of floods and sort of the average conditions or maybe seasonally. And then the third thing that civil engineers usually don't do but they really ought to is try to figure out all the people, who is there that wants something from that basin maybe logging, flood protection, drinking water, irrigation water, groundwater. Look at the different groups that want something and what are the organizations state, local, federal government interests that are organizing people to manage those interests. Because nobody in this business does anything by themselves. It's always groups of people. So the organizations really matter.

**H:** Yeah so kinda looking at those three different layers to more understand the area before we kind of begin the research to take everything into account.

**JL:** If you organize the problem in that way you at least have, you won't be completely clueless.

**H:** Yeah I think that's everything, Joe do you have anything else you want to add.

**J:** Nope all set

**JL:** Well good luck with your project. And your courses.

**H and J:** Yes thank you very much we appreciate it.

**JL:** Ok bye bye

**H and J:** bye

## Land Change Expert/Land Manager

Talking to a land change expert and land manager helped us to understand how climate change and land change are involved in development of their management plans. We also learned what indicators they look for and how natural disasters can affect land change.

### William Gould

Summary table of key points from interview.

<b>Role/Experience of Interviewee</b>	<ul style="list-style-type: none"><li>● Research ecologist with the USDA Forest Service</li><li>● Worked in Colorado and Alaska<ul style="list-style-type: none"><li>○ Assessing vegetation patterns along climatic gradient</li><li>○ Controls on biodiversity patterns</li></ul></li><li>● Landscape patterns<ul style="list-style-type: none"><li>○ Vegetation cover, land use, biodiversity, conservation mechanisms<ul style="list-style-type: none"><li>■ Relationships with climate and species distributions</li></ul></li></ul></li><li>● How conservation interacts with climate change and effects ecosystems management</li></ul>
<b>Summation of information from Interview</b>	<ul style="list-style-type: none"><li>● Indicators<ul style="list-style-type: none"><li>○ Change in vegetation and land cover, impervious surfaces and forest types and degrees of forest cover, degrees of man made cover<ul style="list-style-type: none"><li>■ measure of greenness and loss of canopy and leaf cover</li></ul></li><li>○ Landslides after hurricane<ul style="list-style-type: none"><li>■ where they occur, what was there before, characteristics in terms of slope, rainfall, etc</li><li>■ Interested in how landslides affected sediment load</li></ul></li></ul></li><li>● Runoff will be swifter and greater on impervious surface - sediment load</li><li>● Look at the long term trends in climate change</li><li>● Interaction with rivers and freshwater systems<ul style="list-style-type: none"><li>○ Storms: flood conditions</li></ul></li><li>● Gradual warming trends and drying trends that affect human activity and vegetation cover, affect suitability of different species that change environmental conditions</li><li>● need to educate and create awareness of value from reforestation, planting fruit, wood, need to develop markets, put the social and business aspects together</li></ul>

	<ul style="list-style-type: none"> <li>● 2017: Loss of power, communications, and impacts of down trees, throughout Caribbean and Southeast United States</li> <li>● How to create a more equitable distribution of resources</li> </ul>
<b>Information directly relevant to our project</b>	<ul style="list-style-type: none"> <li>● Recommend vegetation cover if there is none or mitigation of runoff like cagement ponds <ul style="list-style-type: none"> <li>○ Slow runoff from residential or urban areas</li> <li>○ incentivize or educate people (rain gardens)</li> <li>○ slow down sedimentation</li> </ul> </li> <li>● benefits from the management actions that will come from our recommendations <ul style="list-style-type: none"> <li>○ ecosystem benefits</li> <li>○ into the future</li> </ul> </li> <li>● Fix disconnection among groups in terms of how they plan for, respond, and recover from hurricanes</li> </ul>
<b>Possible followup information/contacts given</b>	<ul style="list-style-type: none"> <li>● Possibly follow up with any USGS remote sensing data or other technical aspects</li> </ul>

### Transcription

**Heather:** [Project description]

**Bill Gould:** Sure. What is the timeframe of your study? Just to get a sense of how much effort and time you have to put into it.

**H:** Yeah so project prep started in January and ended in mid march. Then mid march we started the actual project, and we will complete it by May 13th, the end of the academic school year.

**BG:** Good to know. You're not starting a three year project then.

**H:** No, but sometimes these projects carry over from student groups from year to year. So it is possible a group next year will continue work or work off of this project.

**BG:** Are you guys working with a particular person at the DNER?

**Joe:** Yes, we're working with a land manager, Marienlly, and Rafael, what is his exact role?

**H:** Rafael is part of the DNER and Marinelly manages the La Plata region. So we're working with them who are heading this project as it relates to La Plata.

**J:** So normally, we would actually be there but for obvious reasons we can't be. Which is unfortunate but they're like our eyes on the ground there.

**H:** Do you have any further questions before we get started?

**BG:** Lets see so you're trying to finish in May. What do you deliver? A final report with some methodology and conclusions?

**H:** Yeah we have a final report that goes in the WPI database with our methods, intro, background, the results or any data we've collected and a conclusion. But with that we also provide a recommendation to our sponsor so what that looks like we haven't figured out. That's part of the process of the project. Theoretically by the end of this we recommend to them that they keep an eye on land change in a specific area of the river upstream from the refuge or to make sure to keep in consideration the effects of hurricanes in the area and how to plan for those in the future to

limit any land change to the space. Then we have a final presentation to display our findings and give them any files they may need to continue working on their own.

**BG:** Okay, well let's fire away, I am ready.

**J:** So you're interesting to us because you work with land change specific to the Caribbean which is great because you've seen all these changes that have happened. How long have you worked in this field?

**BG:** 20 years I've been here.

**J:** Have you worked anywhere else?

**BG:** I was working in Colorado and Alaska prior to coming to Puerto Rico but my work with the forest service started 20 years ago. But my work as a landscape ecologist probably 25 years ago and most of that work was in the arctic, Alaska and Canada.

**J:** What specifically did you do while you were there?

**BG:** You mean that early work?

**J:** Yes, the early work.

**BG:** Well I was assessing vegetation patterns along a climatic gradient looking at the controls of climate and landscape heterogeneity on biodiversity patterns along a river in the Canadian Arctic. That was most of my work, other projects as well but that was the bulk of it.

**J:** In your work with the United States Forest Service what has been your main focus of work?

**BG:** My main focus is on landscape patterns of vegetation cover, land use and biodiversity and conservation mechanisms that are associated with those patterns. So biodiversity and conservation and in most of that time looking at the relationship of climate with species distributions, and vegetation cover. Now I'm mostly focused on climate change and how that affects both natural landscapes but also agricultural landscapes. And how climate and land management, like conservation areas and mechanisms, all interact with climate change and how those interactions affect ecosystem services and agricultural services.

**J:** Okay, great. Heather, do you have any other questions?

**H:** No I think some of the things you've brought up we'll get more detail. So on a broad scale, how do you assess any land change that you're seeing? So what indicators are you looking for? Things you are measuring daily, weekly, monthly? What tools you're using, any databases?

**BG:** Well you kind of alluded to it that you can look at it at different scales, different time scales. One of the primary tools you have looking at regionals scale or island wide scale or smaller scale is looking at the vegetation cover and the change in vegetation cover, or change in land cover. It may range anywhere from impervious surfaces to a full grown forest and everything in between. So you can detect different kinds of forest types, different kinds of degrees of forest cover, different kinds of degrees of man made cover, impervious surfaces and developed land. So remote sensing tools are great for assessing those things, and now there's different remote sensing tools that are available at different resolutions. Spacial resolutions, time scales, and so you can use those tools depending on the specific questions you're looking at to get an idea of land cover change. Some other ways we look at change are looking at specific events and what the effects were of those. For example, after the hurricanes in 2017 we did some analysis that looked at a measure of greenness. I don't know if you guys do remote sensing.

**H:** Yeah, we are.

**BG:** We did an analysis of the loss of canopy cover, loss of leaf cover. You can measure the greenness from satellites. So that was a way of looking at the change of a specific event you know not necessarily long term change

trends. We also looked at different scales at the landslides after the hurricane at the island wide scale with some USGS remote sensing data. Also at the farm level and also sub farm level we looked at where landslides occurred, what land cover was there before the landslides, what the characteristics were where they occurred in terms of slope, aspect and soils and the amount of rainfall received during the hurricane. In that case we were interested in how those landslides affected the sediment load of streams so that's something you can measure. We didn't in this particular analysis but you can also look at that change in stream sediment load and that will give you some indication that upstream things are changing as well.

**H:** Yeah sediment is a big concern especially with the dam at the reservoir there and the life of that.

**BG:** You can also look at gradual change at the flat scale where you measure tree heights and diameters, you get a measure of growth rate or species composition. You get a measure of the change in turnover of species or something like that.

**H:** So you mentioned remote sensing USGS data, out of curiosity is that available on their website? We've been all over the website.

**BG:** Yeah I'm not exactly sure where we got that. I'd have to check. There was some analysis of landslides after the hurricane. I don't know if they were on a special location.

**H:** Yeah I think we can further look into that.

**BG:** Yeah and there have been some publications if you do a quick google search of landslides after Hurricane Maria. I'm sure there will be a few publications that come up

**H:** Yeah they've got multiple publications

**BG:** And you can check on the data sources. I remember there were some initial estimates and that is what we used in a paper looking at landslides and canopy loss. Then I remember there were subsequent publications that were more refined with high resolution imagery analysis that came out a little bit later.

**H:** So how does the study of this land change affect any management plans that you recommend or any mitigation processes to kind of prevent some of this change from happening cause climate change is obviously not going to go away and the impacts of that could become stronger. So anything that is from the land change assessment that is affecting the management and conservation aspect.

**BG:** I think if you use Río La Plata for an example it has a particular footprint, the watershed, that's where the sediment is going to come from within that watershed upstream of that reservoir. Having a look at where landslides occur from a big storm event gives you an idea where they are likely to occur again. That's a tool you can use. You can identify those areas of concern. You can also look at existing cover and identify areas of bare ground or impervious surfaces within that footprint or forest cover, different amounts of canopy cover. You know that runoff is going to be swifter and greater on bare ground and impervious surfaces. Those are areas of kinda interest in terms of looking at sediment load. You can sorta characterize those in terms of priorities. And if you have areas of low vegetation cover but high potential for sedimentation like steep slopes, areas where landslides have occurred in the past, areas that are perhaps closer to the reservoir. Those might be a way you could prioritize for some kind of management action. That management actions would be recommending either some kind of vegetation cover if there is none or some kind of mitigation of runoff from impervious surfaces you can have cagement ponds that slow down the runoff. If there are areas of residential or urbanized in some way, you can incentivise or educate people about things like rain gardens. Anything that slows down that runoff is going to help reduce the sedimentation load. You can identify which lands are public and which lands are private. You have more ability to manage the public lands you know DNER does. So those can be prioritized as needing reforestation efforts or some other kind of management action. Right now there is support for reforestation after the hurricane. So that's a good tool to use in the analysis you guys might be doing to kinda target priority areas for reforestation.

**H:** Yeah where we're seeing issues and kinda of reforestation and increasing that vegetation as a way to mitigate landslides and any erosion that is happening. Ok. So more specific to the work you have been doing in Puerto Rico

rather than a broad scale approach, how has the land you have been working with and managing or assessing how has it been impacted by climate change and what have you been doing to look at those impacts?

**BG:** Well there are a couple ways you can look at it. And one is looking at the long term trends as to what we're seeing and what we expect more of with climate change. There are impacts that are dependent on where you are in the landscape. There are a lot of coastal impacts that may not be relevant on the interior part of the island and vice versa. You can kinda characterize the effects that you're expecting as to what part of the landscape they most effect. We have sea level rise and salinization issues related to climate change that affect both the developed areas along the coast and also the agricultural lands along the coast. And sea level rise is in one sense a gradual process but you see its effects most often when you have storms and high storm surge because you have combined effect of more frequent intense storms and those storms bring with them greater storm surge. So you see the effects of that along the coast. There is an interaction with rivers and freshwater systems because those storms also bring with them flood conditions so you can have increased flood risk due to a particular storm that is a combination of more water, high volume of water coming down the river and also higher storm surge that pulls that water back into the coastal system. We are seeing that effect in more coastal damages we are seeing an increased rate of sea level rise, increasing storm surge and more effects to infrastructure along the coast. You guys might be thinking, well we're working with the landscape around the reservoirs and maybe that's not connected with the coast, but anything you do in the interior part of the island that reduces the risk of flooding, slows down that water flow, reduces sedimentation in the reservoirs, that is going to help mitigate those coastal concerns that are due to sea level rise and storm surge. That is one aspect of things we're seeing, things we're doing is making those connections between management actions and climate change effects. Another effect on the rader are the gradual long term warming trends and potentially drying trends that we see. And those they affect human activity but they also affect vegetation cover. They affect the suitability of different species, they change the environmental conditions. I think in the case of what you guys are working on it is probably most relevant when you think about management actions like reforestation or revegetation of some kind. When you plant a tree you're hoping that it's going to live there for 40, 50, 60, 100 years. It's a long term prospect. You want to be most successful. Your idea is stabilizing slopes and providing other benefits from trees so biodiversity and native species. You want to protect that investment by looking at future climates. And thinking how is this going to do, how does this species do with potentially warmer nights, more extreme heat days, more potential days between rain storms which is one of the things that we are observing. You can think about reforestation recommendations and very specific species adaptations to future conditions as opposed to just thinking conditions are static. And we plant what's growing there now and it's going to be fine in 40 or 50 years. I guess one other thing to mention is also to think about the benefits that you're expecting from the management actions that you recommend. The ecosystem benefits that we like to get from managing forests and landscapes. They're really defined by society in a way, what people see as beneficial. Those also you need to think into the future, not necessarily think that this is what society needs right now so we manage for this. In terms of climate change you can think about how those services will change and how the value of those services will change in the future with potentially warmer, potentially dryer, potentially more frequent disasters that are climate related droughts and storms. So as an example, we've been working a lot with trying to reinvigorate the wood industry in Puerto Rico. We have millions and millions of trees that were downed from the hurricane and essentially treated like trash. The plan was to clean them out of the streets, burn them, or put them in landfills. But there was a recognition that within all that vegetated debris there was material of value. Things you could compost, things you could make wood chips with, things you could make biochar. There were also tropical hardwoods that on the global market have a value of \$20-\$30 for a piece this size [shows with hands]. And there were millions and millions of chord feet. We didn't have the industry and the capacity to take advantage so most of that was lost. Millions of dollars of value lost. So thinking into the future and how you could recover these benefits or provide benefits from something like that to society. And you're thinking about reforestation and land management. You can try to integrate some benefits that we can't really get right now but we could if we had markets, if we had education, if we had awareness of those benefits. That might be something like how to get some value from wood that you salvage from a forest, it doesn't necessarily mean the timber industry. It might mean part of your reforestation would have fruit trees and they might be a fruit that is a native species that doesn't really have a market but if you develop a market in local restaurants for this. There might be traditional knowledge but no market, you might put those pieces together and then build into your management recommendations for a particular species where in the future you expect markets to grow for that kind of forest product that you might develop. We have seen these effects of increased storms, shifts in species compositions mostly from birds and some amphibians related to warming and in terms of managing for the future you have to think both about those environmental conditions that are changing but also social conditions in terms of what do we want from the landscape and realize those benefits. What kind of

pieces have to be promoted or incentivized and how do you educate people that those benefits are possible from the landscape. Part of our job at the climate hub is trying to advise what are the best actions for the future

**H:** Yea and not just choosing actions for today and tomorrow but for 20-30 plus years from now. We're interested in what impacts and effects you saw from Maria and Irma and the series of earthquakes in 2020 and any impacts you saw from those

**BG:** Tons of impacts from the hurricanes a number of studies that we did and some published and in process take home messages were that there is a general agreement on some of the key effects from agencies like landowners to farmers that the key effects were the loss of power, loss of communication, and impacts of the downed trees. And so this was something not only in Puerto Rico and US virgin islands but throughout 11 states in the Southeast after 2017-2018 and the same key impacts were identified by people. And in the case of the Caribbean those were over an extended period of time the loss of power and the loss of communication. One of the key findings we gathered from interviewing different focus groups from farmers and land managers from agencies that were responding was that there was a lot of disconnection among those groups in terms of how they plan for and respond and recover from the hurricane so that's a need that's identified. We expect more big storms like this so we have to learn from them and try to respond better so they aren't so disastrous. And the lack of connectivity expressed itself in the planning stage for example individual farmers have a personal plan based on experience, so people make personal plans and preparations but often do it at different scales, municipalities has plans, fema has plans, PR government has plans, but often the plans are disconnected so you don't get any benefit for example, farm country had no access to their land because of downed trees so their plans were using chainsaws to cut the trees but the municipalities could have the equipment to use. But the farmers don't know what the municipalities can do for them. So nearby municipalities have the equipment to use, and the farmers have the people to operate, but no connection between those two entities so the heavy equipment just sat there unused. One example of disconnection at one level. But disconnections are going on at many levels and a consequence of that is how connected you are has an effect on the resources you get in the recovery period so we also recognize a lot of inequality in the resources that go to planning and response and recovery and all of that stuff that is related to how connected you are to the resources so that is something we learned from that experience so a challenge is how do you improve that connectivity and how do you equitably distribute resources. For example a lot of coffee farmers lost their plantations and there was a shortage of coffee seedlings and so there were lots of national organizations that want to help so there was a big influx of resources but they only came to some farmers because of that connection and the farmer next door may not have had that connection so they didn't get any resources meanwhile someone down the road has volunteers from Starbucks who are helping rebuild the farm. So we saw that over and over again a lot of inequality whether it was food or power resources and that's something that we learn from the experience and were trying to work to improve. And it boils down to reforestation projects and watershed levels how resources go to that so that's where studies can prioritize areas for management actions and those are on the table and have science behind them then that helps when there is an event in the future and people want to help you can make sure those resources get to their most needed to make improvements.

## Public Water Department Employees

Public water department employees gave us insight into how reservoirs are impacted by natural disasters. Interviews also helped us to understand what indicators are monitored for reservoir management. Looking both on a day-to-day basis and when preparing for or recovering from a severe weather event.

### Francisco Catalá Míguez

Summary table with key points from the interview.

<p><b>Role/Experience of Interviewee</b></p>	<ul style="list-style-type: none"> <li>● Works for DNER as an environmental planner             <ul style="list-style-type: none"> <li>○ 2006-2010, 2013-Now</li> </ul> </li> <li>● Organizational work and field work</li> <li>● Working on Salinas aquifer - municipality depends on wells in it</li> <li>● Coordinates with multiple agencies that own different pieces of the project</li> </ul>
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	<ul style="list-style-type: none"> <li>● Checks USGS gauges for droughts and reports once a week</li> <li>● Preservation of river sections, focuses island wide but will focus on areas that need more attention</li> </ul>
<b>Summation of information from Interview</b>	<ul style="list-style-type: none"> <li>● Helpful information <ul style="list-style-type: none"> <li>○ <a href="https://storms.ngs.noaa.gov/storms/maria/index.html#10/18.1782/-66.2877">https://storms.ngs.noaa.gov/storms/maria/index.html#10/18.1782/-66.2877</a></li> <li>○ <a href="https://data.noaa.gov/dataset/dataset/c-cap-land-cover-puerto-rico-20101">https://data.noaa.gov/dataset/dataset/c-cap-land-cover-puerto-rico-20101</a></li> </ul> </li> <li>● Gave insight on work affected by Hurricane Maria <ul style="list-style-type: none"> <li>○ Building damages, delayed projects and reports, high storm surge</li> </ul> </li> <li>● Conservation or management impacted from storm <ul style="list-style-type: none"> <li>○ Problem with dam sediment and blocked river near bridges</li> <li>○ Supplying water in western side of island due to changed river course - leaving water supply stranded</li> </ul> </li> </ul>
<b>Information directly relevant to our project</b>	<ul style="list-style-type: none"> <li>● Drought monitor used by USGS and public water agency data finds quality and extraction</li> <li>● Planning board does more land use work - they give advice on areas that need to be preserved and submit plans for the area but do not choose the area</li> </ul>
<b>Possible followup information/contacts given</b>	<ul style="list-style-type: none"> <li>● Look for La Plata report that took up sediment during 2005/6 drought</li> <li>● Compare management of La Plata vs. others and how some are managed by power authority</li> <li>● Contact Greg Morris</li> <li>● Power authority contact</li> </ul>

## Transcription

**Joe:** [describing project]

**Francisco Catalá Míguez:** Let me tell you what I do at the Natural Resource Department. My office is in charge of coordinating the projects that are in the Water Resource Management Plan, the plan is revised every 8 years, takes assessment of water as a resource, not just drinking water. Integrate everyone into the plan - domestic, agricultural, industrial and conservation which is ecological use. Maintain a balance, not dry the river up so you can have fish and other activities at the same time as using water for another resource, economic or social. Right now we are running three projects. My office used to be 8 people, 2 biologists, an engineer, a planner, my boss and a secretary. Now those are gone and only left two, just two planners. Most of the projects in the plan cannot be carried out because we are just two people there. Some of the projects are suggestions to other agencies, island wide the reservoirs are managed by 3 agencies. PRASA, PREPA, power authority because there are still some dams that are used for generating electricity, and two of the others are owned by the Department but those are for flow control. But there's one that has a component of subplanning(?)

**Adelaide:** How long have you been working in this position at the DNER?

**FCM:** I started there in 2006 I think, then in 2010 was the economic crisis so many people got laid off and I was one of those. So I spent 3 years, almost 4, doing other stuff. I worked at the craft store in old San Juan and doing private consulting. Then I got back to the Department in 2013 and I've been there since.

**A:** Have you always been in this position or have you moved around since you left and came back?

**FCM:** I've always had this position.

**A:** What do you do as an environmental planner in general?

**FCM:** Right now the projects I am coordinating the recharge of the Salinas aquifer. Salinas is the only one in PR that depends entirely on wells in the aquifer, there is no superficial source of water. Since they have grown, the aquifer has been polluted by Salinas intrusions. The idea of the project is to use the old agricultural canals and some ponds to flow water from the Patillas dam to there. Since the canals are not concrete, they are earth, they will percolate and help to stabilize the aquifer. That is done by FEMA and some other local agencies, so most of the time it is trying to coordinate the agencies, that is the big problem. Try to get the power authority in because the canals are owned by them, try to get the land authority in because the ponds are theirs, and try to get the Puerto Rico water agency in because they will benefit because some of the wells are theirs and they supply drinking water to the population. Trying to get all these people in is kind of difficult.

**A:** So do you help with coordinating all the different groups?

**FCM:** Yeah, and you think that's kind of easy going but no sometimes I spend a couple weeks trying to reach someone. And the other thing we are doing, right now there are some dry patches in the north part of the island, so we every week do a report on that and we check on the USGS gauges and some of the key rivers. And we gather together the data and do that report every thursday. There's a committee on that and right now every month we hold a meeting and discuss how the drought is going, and if water supply needs to be adjusted. And conserving water, try to lower down the pressures and save water. And if the thing gets too out of hand, then plan rationing water. The last drought here started around 2016 until 2019 or early 2020. One of the problems was at La Plata, I think they had a shortage of water there.

**A:** We've found a lot of information about 2015 to 2016, was that when it was the most severe drought?

**FCM:** I think that the drought in the 1990's was harder. I'm going to send you a contact for an engineer, he does a lot of things hydrology. He has written a lot about sedimentation in reservoirs. That's a problem at La Plata and some other reservoirs. He's always complaining they don't have the management at the reservoir to operate the gates. You get a heavy rain, open the gates so the water with the sediment will go through, then you close it and get the water with less sediment. He has talked a lot about that. He is from the US but has been living here for half his life, his name is Greg Morris. You can talk with him in Spanish or English. The other thing we are doing in the office is the scenic river program. We are trying to find pieces of stream, about a km long that have some interesting(?) characteristics and trying to do some preservation of those. But those are the three main things we are working on right now. Once in a while we get a project or development or they ask for advice so sometimes we have to write down and present projects but that's not common.

**A:** Do you usually focus on a specific part of the island or is your work all over?

**FCM:** Supposed to be island wide but right now I am concentrating more on the south part of the island, but the drought report is island wide.

**J:** If this applies to you, how would you say your work has been affected by hurricane Maria or the earthquakes?

**FCM:** The earthquake didn't have much effect but the hurricane it did. The building where I work was surveyed damaged, especially the open floors. My office then was in the middle so didn't happen much. But the windows got blown away, and we couldn't start working there until November. It was almost a month and a half before we could go into the building. I couldn't do much of my work so I hooked up with the people at the coastal management, they were doing some assessments in the coastal areas. Checking how far in the surge got so I helped them out with GPS and went into the field with them, but my work I couldn't start until november. And that delayed the project on the aquifer in the south, severely, and reports we couldn't do anything because we didn't have any power. The power generator at the agency had some issues so it was working for a couple days then shut down again. It disrupted work for several months and of course we didn't have a plan B then. Because we didn't have a hurricane like that. One of the interesting things when I was in the field with the guys of the coastal zone, we were in the area where the hurricane entered, Yabucoa, that's southeast. So I asked a guy, he was about my age, has he ever seen the surge go

so far in. And he told me never, but then he remembered and told me about his grandfather. So when he referred to him I said he's talking about the San Felipe hurricane which hit us in 1928. So the grandfather had passed away, he was telling me as a kid his father telling him stories about that hurricane. So this hurricane Maria was almost as strong as San Felipe almost 100 years ago. You know, here's someone talking about it, that he remembered from his grandfather was interesting because he is talking about oral history. Keep passing on the story.

**J:** History repeats itself.

**FCM:** what else?

**J:** After, when you got back to work how was conservation or management impacted by the damage?

**FCM:** What information I got general about the island, there was a problem with some sediment in the dams, and blocked rivers especially near bridges. You have a bunch of trees and parts of houses and garbage stuck in the bridge. There was a problem with the supply plant of water in Ernesto because the river serpents. The thing is the water was so strong in that area that the water cut straight to the coast so that water supply plant was isolated so they had to fix that so they could get water to the population in the west part of the island. So they had to do some quick assessments there, you didn't have time for an environmental impact plan or sit down and start thinking of stuff because they had to fix that right away. Because you have thousands of people without service then you say go ahead and do it, don't ask us. That's what I remember.

**J:** That's what we're looking for so thank you. What weather indicators do you look at that could impact the conservation or preservation of an area?

**FCM:** At least for drought monitors we look at that, we look at USGS data, we receive some data from the public water agency, some quality data and some extraction data. We use those to generate a report. We don't do such as looking at land use, we might do recommendations but land use, that will be the planning board. We do give advice to the planning board which areas need to be preserved, so we prepare the plan and submit it to them. So they then see the area as a protected area but we don't make the area, we recommend that it be preserved. So that's why we don't have that power. That can be a problem because sometimes there are conflicts of uses, you say we need to preserve that but you may have it as agricultural land so they want to use it or develop it and there are conflicts sometimes there.

**J:** Do you have anything else overall you want to add about our project or what you do, anything that can help us?

**FCM:** La Plata took out sediment in the drought in 2005 or 2006, I don't know if they have any information on that, how much sediment they took out or that or any documents. The problem is that sometimes most of the documents are in spanish and few of them are in english. Of what I got the only thing I have is some documents in english are from the project I'm doing in the south part of the island because I need to send reports to FEMA so all of those are in english, but most of the others are in spanish. I do recommend you to contact this guy Greg Morris, I will send you his email. I don't know if you were able to contact the person in PRASA, I think Ann Pentura is her name.

**A:** I sent an email 5 or 6 days ago but haven't heard anything yet.

**FCM:** I don't know if you want to compare how they are managing La Plata versus other reservoirs in PR because some are managed by the power authority. I don't know if you need a contact there to interview him. I do have a contact and I can send you his email if you want.

**A:** Well take it if it's not too much trouble for you.

**FCM:** I have those. Those two contacts will help you out. I don't know if you are lacking information I can provide from the agency or another source.

**J:** I think that's everything for now.

**FCM:** Are you doing GIS assessments of the area? I have a large layer called the gap analysis layer, that's a clustered layer, depending on the colors they can anticipate: grassland, forest, urbanized. It's an item wide layer. It's kind of old from the late 90's early 2000's. It could be useful if you don't have that layer.

**J:** From after 2003 would be most useful

**FCM:** I will check on that because I could burn a DVD and mail it to you, or put it in drop box.

**A:** could be helpful either way just to see what's there and how things have changed

**FCM:** Aerial photography the lasts I got is 2010

The thing with the data is that i don't have it here, and some days at home some at the DNER. The data is there so monday I can check on that and send you the contacts today.

**J:** All we have and thank you

## Gene Camargo

Summary table of key information from the interview.

<p><b>Role/Experience of Interviewee</b></p>	<ul style="list-style-type: none"> <li>● Worked in Rockport for 2 years             <ul style="list-style-type: none"> <li>○ Started as Supervisor operations</li> <li>○ Now in public works realm of management</li> </ul> </li> <li>● Worked at other water departments before this one, about 80 miles up the road</li> <li>● Mostly does office work - works with Juan who oversees much more of the field work</li> </ul>
<p><b>Summation of information from Interview</b></p>	<ul style="list-style-type: none"> <li>● Within the town most of the houses are vacation homes             <ul style="list-style-type: none"> <li>○ Makes it difficult to detect where problems may be after a storm because the people are not there to tell them</li> </ul> </li> <li>● Communicate with neighboring towns and municipalities about water resources</li> <li>● Receive water from the Choke Canyon Reservoir on the Nueces River and Lake Corpus Christi             <ul style="list-style-type: none"> <li>○ These are upstream in neighboring towns</li> </ul> </li> <li>● When water lines break - with Harvey and Uri - it was more local pipelines to houses, no breaks in main lines             <ul style="list-style-type: none"> <li>○ They put houses on 8-5 water use schedule to conserve water                 <ul style="list-style-type: none"> <li>■ Also helps them because it's easier to find water line breaks in the daylight</li> </ul> </li> </ul> </li> <li>● During natural disasters or when there is high damage the facilities at the water department become shelter and "home" for the workers - they have showers, food and beds for them because many of their houses may not have power or water</li> </ul>
<p><b>Information directly relevant to our project</b></p>	<ul style="list-style-type: none"> <li>● Hurricane Harvey and other hurricanes have more of a concentrated effect because Texas is so large             <ul style="list-style-type: none"> <li>○ Usually coastal towns are more heavily impacted than inland</li> <li>○ This also allows them to receive resources faster because nearby towns can supply them</li> </ul> </li> <li>● Winter Storm Uri impacted the whole state             <ul style="list-style-type: none"> <li>○ More similar to how hurricanes impact Puerto Rico</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>○ Power outage and water impacts were longer lasting because all the neighboring towns were impacted as well and they couldn't help each other out</li> <li>● They have a committee of officials in neighboring towns that meets when there is a storm approaching in the Gulf <ul style="list-style-type: none"> <li>○ The group creates an emergency plan and stay up to date with weather information</li> <li>○ Then have a meeting with officials in their county to create solid plans</li> </ul> </li> <li>● During drought they follow the same regulations as neighboring towns so that everyone is on the same page and helping equally</li> </ul>
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**Transcription**

**Heather:** [describing project]

**Gene Camargo:** Ok.

**H:** So before we begin, do you have any questions for us about the project?

**GC:** No, just that we're on a peninsula and we receive our water source from the Nueces river that serves several communities in the city of Corpus Christi before it gets to us also. So we're kind of in a regional water distribution system although we control the water once it enters our municipal boundaries.

**H:** Sounds good. Yeah I think one of the reasons were interested in interviewing you is because of the impact hurricane Harvey had in the area and you know similar issues with hurricane Maria have happened in Puerto Rico as well.

**GC:** Right. I think there's such a contrasting social economic populous. Rockport tends to be a vacation spot. Probably about maybe 2/3 of our residences are owned by people somewhere else, Houston, San Antonio, Austin. I am familiar with Puerto Rico, that's a big difference of how hurricanes affected them. And I'll answer your questions; however, Hurricane Harvey did cause a lot of wind damage but we did not anywhere experience the tidal surge that Puerto Rico did. Although there were some effects to the community of Port Aransas on their gas system them being closer to the gulf than we were. There were some infrastructure impacts. Juan was here during the storm. I wasn't but we can tell you what happened and what we had to do to our water system to get it up and running. And recently we just went through with winter storm Uri and the impacts of the power outage and those impacts were very similar to what we experienced during hurricane Harvey and I can further explain that.

**Adelaide:** Yeah so were interested in how you sort of plan for or recovered from damage that occurred. We can start though with some introductory questions just to understand you work a little more. So how long have you worked with the water department in Rockport?

**GC:** Two years and Juan going on 10. So I was not here for Harvey.

**A:** So did you work at other water departments before this?

**GC:** Yeah so I ran a small municipal water system up the road about 80 miles.

**A:** what's your role within this department?

**GC:** Assistant public works director. I supervise water, sewer and gas operations.

**A:** I'm going to assume you've been doing this for the past two years since it's only been that long or have you changed rolls while you're there?

**GC:** Say that one more time.

**A:** Have you had the same role the whole time?

**GC:** No, I started out as more of a supervisor of operations and now I am in the public works realm of management, budgeting and some other things. I think.

**A:** So what do you do on a daily basis? Are you mostly doing office work or do you go out and do things like in the field?

**GC:** I try and get out of my office, but I am mostly office. Juan is more in the field and does day to day operations. He is really in charge; he just won't admit it.

**A:** What kind of things are your day to day operations, like what does that look like? Is it

**GC:** Installation of water meters, gas meters for new construction and growth, daily maintenance operations, monthly billing, meter reading, turn off, turn ons, leaks, customer leaks, customer issues, sewer backups, wastewater treatment plant operations. We have 42 lift stations for roughly 10,000 people which is a high number of lift stations per number of people but it had more to do with our terrain and being extremely flat.

**A:** yeah does your work usually branch outside of the town or do you stay within the city?

**GC:** So if you look at a map of where we are at Aransas county. 188 south is our boundary to the south and if you draw that line across the peninsula everything north is in our, is either in our city limits or in our ETJ[extraterritorial jurisdiction]. Pretty much

**A:** Ok.

**GC:** We're not an island but were surrounded on three sides.

**A:** Yeah, what is your, cause we were reading on your website it seems like you have mostly, like there's not a reservoir directly in Rockport but you're fed from one?

**GC:** That is correct, our water supply comes from the San Patricio municipal water district that contracts with the city of Corpus for river rights running up and down the Nueces river. The other supplemental supply that Corpus and San Pat have is the Mary Rose pipeline that comes from Lake Texana and I think that amount is 25,000 acre feet. And then I don't know the exact proportion of the water district that provides those [unclear audio]

**A:** So are you involved at all in like monitoring those water levels or just mostly that information?

**GC:** Yeah now it's become a common occurrence on every evening weather forecast that they have the capacity of Choke Canyon that feeds into lake Corpus Christi, lake Corpus Christi then enters into Nueces and then we draw water, San Pat draws water and Corpus draws water from that river flow. It's become common occurrence that on every daily weather forecast they give you the level at Choke Canyon reservoir which is upstream and then lake Corpus Christi and then they give you a combined capacity and then we monitor that. Then that combined reservoir capacity dictates our drought restrictions and water restrictions, when to cut back and we're currently in stage 1 of that drought plan.

**H:** So we can move on to maybe a little bit more specific questions related to the natural disasters that we've talked about. So I know you haven't really worked with Rockport during Harvey but you mentioned you were there this winter during that winter storm. So I guess how is your work affected by these events that have been happening?

**GC:** Tremendously because when the storm hit. I'll talk to water and Juan can talk to gas. The number of houses that were damaged also had water meters broke, lines broke and everything. Rockport didn't have huge main brake right large mains broken, but the amount and this is very similar to the winter storm we just faced. The amount of water connections that were damaged we were bleeding like the sea, water was just flowing out. And I really feel that the

winter storm Uri was more impacted upon us because during Harvey there was a set landmass area that was affected by the storm whereas hurricane Uri and that could snap lets see to the south of me and all the municipalities were also effected. During hurricane Harvey, Corpus Christi was spared from damage. During the winter storm city of Corpus Christi issued boil water notices all the municipalities around us issued boil water notices because of water line breaks and because of customers not being able to maintain system pressure and even as far north as the city of San Antonio was affected. Hurricane Harvey to me, other than Houston which had flooding, the city of Rockport during Hurricane Harvey was effected by the number of connections that were broke and we had to shut down the water system and issue boil water notice and draw on the system on a day to day basis our guys had to go out and shut these meters off to quit bleeding water. That was the same, thank god for Harvey in this sense my guys were prepared during the winter storm to do the same thing in fact while I do have a water and waste water department Juan's gas guys chipped in to shut down these metered connections to quit bleeding water out to bring our system back online.

**H:** yeah so because the department had kinda gone through some similar issues in Harvey you guys had the tools to adapt to a different type of storm but similar effects.

**GC:** Correct

**H:** Ok. So I guess speaking on that a little bit, what were some of the tools and systems used to prepare for the damage that comes from storms such as Harvey and Uri?

**GC:** So after Harvey we initiated fuel contracts that whenever hurricane season comes around and we get a storm in the gulf that looks like its going to hit we now have a contract with someone that brings us backup fuel supplies with generators here during Harvey. We have backup generators here at our service centers which is very important cause during Harvey when the storm scattered everyone here at least we had showers we could cook and we had power. And also we initiate just like we did during the winter storm. We locked up about 90,000 gallons in our elevated storage here at our storage center so that our guys could shower and they're out there addressing the effects of the storm so they need some place they can come to to find food, clothing and shelter.

**H:** So it sounds like you kind maintain the area under Rockport that you kind of served under this department like your maintaining this area during these storms by providing generators and ways to keep the system running despite power outages and minimizing runoff and overflow with any burst water lines and etc

**GC:** Right so we have sewer also that leads into the lift stations If the lift stations don't have electricity to them certain precautions need to be taken to prevent sewer overflows from these stations. People need water to wash hands bathe clean up and everything. So we maintain facilities that are storm proof so that our guys can do what they need to do operationally within the city limits or ETJ to get our system and certain utility services back up and running for the public.

**H:** Sounds good, makes sense. It sounds like you guys are pretty well prepared for events like this but I guess more for Harvey when you likely weren't as prepared what sort of reaction does the department have and what steps are taken when you guys are kinda hit with this issue that you don't have the tools set in place yet?

**GC:** Well let me start with telling you the Pros. The pros of going through Harvey is that now when we have a natural disasters such as Uri or another hurricane we know what because there's FEMA dollars that qualify for release. We know better how to do that paper work and handle that process Ok. Our response for Uri was a recognized disaster we already knew what paper work we had to do. We already knew better what documentation we had to do so that helps being prepared in that manner, knowing what you're supposed to do instead of after the storm trying to think oh no. Communication we Harvey was different in that we lost cellphone communication. Here we maintained it with this last winter storm but communication is very essential. We did some day to day meetings that I think helped Juan can maybe say yay or nay, but we had to coordinate efforts. We learned to communicate. We learned to give out tasks that are during times of storms. I think areas that we can probably improve is like during the winter storm Uri and even Harvey there were people that chose to leave the area or not have to come to work. What we can improve is knowing who we're going to bring back during these natural disasters. In other words if Juan is told ok you get to stay home Thursday right but we really need him being more clear and upfront about who essential personal are during natural disasters and we just had a re-examination. The key thing is to bring these

people back automatically in preparation for that disaster whether they are needed or not and that's probably what we've learned.

**H:** Sounds good so moving off of that was conservation, my assumption is yes, but was conservation and/or management impacted by the storms and if so how?

**GC:** Well if we shut the water off you better conserve what we have for you right now.

**H:** exactly.

**GC:** What we did is we implemented an 8-5 in this last winter storm and during Harvey it was similar right it was on during the day, so it was conservation in that I think we had to. if we let them have water 8-5 and then we would store up and build our tanks up and then we could do it again the next day until we stabilize the system. I'm just going to give you. In winter storm Uri the lines were busted we turned on the water 8-5 because 1) we had to build up our reservoir to serve people but 2) we could not during the night to find the leak and shut it off is very difficult where during the day it is very visual so that was the other nexus why we kept that time frame from 8-5 to bring that water back on.

**H:** yes you could work during the daylight to find those leaks in the system

**GC:** Leaks that's correct and I think that's an effective once Tuesday we ran the tanks down because we were bleeding more water than we could replenish. We were in a boil water notice by TCEQ[Texas Commission on Environmental Quality] rules. No one wants to be in a boil water notice status but I think it was good because it allowed us to operate bring water on and off without being in violation because we were in that boil water notice and because there were no really ruptures of main lines of distributions the boil water status was probably and don't quote me on this a little overkill. We were extra extra precautionary of these residents boiling water is a good thing. It didn't hurt anything except maybe time of having to do things so from a conservation standpoint. It was mandated conservation there was no voluntarily. The water was on during certain periods of time so you got whatever water and that was it.

**H:** yeah whatever water

**GC:** That being said I think there was probably sprinkler systems that were going off during that time frame that we got shut off. You know we shut them off

**H:** yeah whatever water you let them have that they took

**GC:** Right the downfall or the thing is that we have got a lot of people who own houses, second homes, here and they had no eyes or ears on the ground to shut their house off. They didn't know weather they had a leak or not and they weren't going to come down here. That was the other thing fuel got really scarce because we had power outages Monday Tuesday Wednesday and then back on Thursday so roughly 4 days and all the there was one gas station that I know that was open and some others around but gas supply got limited. So that fuels supply I talked about its very important to make sure that your operational vehicles have a source and are ready to go.

**H:** yes because yeah so any any vehicles you need to send out for repair or maintenance and management after the fact need that fuel and if it's not available you have some problems

**GC:** Right

**H:** Alright so then when looking at these storms you had kind of mentioned briefly that you kind of look towards the weather that you see in the gulf any storms that could potentially come your way what sort of indicators or signs are you guys looking for that could impact how you're managing the water so that if the event does come to shore

**GC:** So as soon as the storm hits the gulf theres a retail group out of Corpus that comprises the counties in the coastal bend and we get a zoom conference and we get the latest greatest NOAA update. As a potential storm threat. as that storm grows nearer than those increase in frequency and the weather reports increase in frequency not only



once we get off that multi county call then we have then a county call to discuss emergency operations and preparedness so that a big plus one getting those weather report and those latest greatest updates but also coordinating activities in the area and the county on how to respond.

**H:** So you're looking at a lot of the storms in the Gulf in any you like wind speeds or tropical depressions that kind of form and bringing your team together to assess what needs to be done in preparation.

**GC:** Right

**H:** okay so in terms of droughts then and other storms or kind of natural disasters on the more dry end I guess what sort of things do you look for like water levels in your reservoirs or rivers anything like that to kind of anticipate when you guys may have a drought

**GC:** Yeah in Texas droughts are frequent and so are delusions and storms. We never get the perfect year we always get the oddball year too dry or too wet but the combined reservoir capacity and the management in the reservoir provide the basis for our conservation measures. In other words when those reservoir levels hit certain levels and that's online with the San Pat municipal water district. When those reservoirs hit that level, activities like once a week lawn watering I think it goes to twice a week and no outdoor car washes. There's a various amount of restrictions that take place to conserve water.

**H:** yeah that residents kinda have to put into the into place so do you happen to know what that level is for

**GC:** No not off the top of my head but I can get that for you and it may be on our website also

**H:** And I think you said San Pat also has that information so we can look there.

**GC:** Yes Ma'am. So just so you know, we adhere to what San Pat has so that all the cities and municipalities within the area are following the same directions you don't want to have one city following one plan and then someone else being different it just confuses the conservation message.

**H:** yeah that makes a lot of sense. Alright then that is all the questions we have for you today unless you have any outstanding information that you feel is necessary but we appreciate you speaking with us

**GC:** I mean I think your report will be interesting to see how Puerto Rico is set up and I am familiar with Puerto Rico having to work with USDA and so they have different governors and Arecibo is different from San Juan how they are governed so I would be interested to see how they handle things. I guess the only message I have that could contribute that could help is regional and county coordination and partnerships are what make things tick. I am kinda proud about the level of information for storm preparedness and preparation goes I think what is probably a more comparable event is the winter storm Uri than the hurricanes. Texas is a big state and you can have a hurricane hit a certain area but when Puerto Rico gets hit with a hurricane it's pretty much the whole island. The winter storm is a very comparative event in that all of Texas was impacted by winter storm Uri. Except for El Paso who is far enough on the west to be tied to the western electrical grid but there were mass boil water notices and water outages in Texas.

**H:** yeah all across the state which is considering the size to state is quite massive

**GC:** Right and so all I am saying when you look at a hurricane event it may be subjected to certain coastal areas and there were resources out by those coastal areas in the state of Texas that could have helped where as the winter hit the whole state. I imagine that's part of the comparative with Puerto Rico. I mean with the whole island down the next palace you go for resources is probably the mainland.

**H:** yeah the western half for the island can't exactly help the eastern half the island cause it's equally affected

**GC:** right and so the winter event is a more comparable event because we were impacted in that same manner of not being able to reach out and have available resources close by.

**H:** Alright, I think we're all set then we really appreciate you talking with us this has given us some good information on how you know it's not the same obviously as is Puerto Rico but in terms of management strategy and do what you guys look for and how you deal with storms you can kind of translate some work over to the people that manage the area at we are working with. We appreciate it

**A:** thank you very much for taking the time to speak with us

**GC:** Well thank you for your interest

**H & A:** have a good day

## Wyatt Arnold

Summary table of key information from the interview.

<b>Role/Experience of Interviewee</b>	<ul style="list-style-type: none"> <li>● Works in climate change program as an engineer of water resources</li> <li>● Has been working with CDWR for 5 years, first places he's worked since graduating</li> </ul>
<b>Summation of information from Interview</b>	<ul style="list-style-type: none"> <li>● In his work looks at hydrologic models and compares them with climate change models and stream flow simulations then develops a report on data found and communicates results</li> <li>● Also does outreach to inform public of available resources and guidance for local agencies</li> <li>● Tracks and supports sustainable groundwater management</li> </ul>
<b>Information directly relevant to our project</b>	<ul style="list-style-type: none"> <li>● Disasters were averted with proper management of an area             <ul style="list-style-type: none"> <li>○ Lake Orville incident with broken spillway, switched to emergency spillway but that was bad too                 <ul style="list-style-type: none"> <li>■ Ended up using broken spillway and evacuated towns downstream, everything ended up okay but impacted the way he looks at work and what dangers to prioritize</li> </ul> </li> <li>○ 2012 -16 drought                 <ul style="list-style-type: none"> <li>■ Avoided major economic loss because lots of groundwater storage so agriculture could continue</li> <li>■ However, there were other impacts with expenses of pumping water above ground</li> </ul> </li> </ul> </li> <li>● Air temperatures are rising, but precipitation values are difficult to measure</li> <li>● Indicators for short term management             <ul style="list-style-type: none"> <li>○ Air temperature</li> <li>○ Salinity</li> <li>○ Flows in channels and delta</li> </ul> </li> <li>● For dams             <ul style="list-style-type: none"> <li>○ Forecasts of stream flow based on condition of upper watershed - soil moisture, snow pack</li> <li>○ Model forecasts of rain temperature of storm and how it relates to expected run off - short term to govern releases from reservoir - also very seasonal</li> </ul> </li> </ul>

### Transcription

**J:** [Describing Project]

**A:** How long have you worked with the California Department of Water Resources

**W:** 5 Years

**A:** What is your role within the department?

**W:** Right now I work in the climate change program as an engineer, water resources

**A:** What do you do on a daily basis?

**W:** So I'd say first is modeling, and when I say modeling I mean hydrologic modeling so converting climate data into stream flow with simulation models. And then from the stream flow I will model system flows, which is reservoir operations and meeting downstream urban and agricultural demands, water rights. And then on top of that I'll look at many scenarios with climate in those models. And documentation and writing and communication that goes with managing that information. And then beyond the modeling and the data let's say the other 20 to 30 percent of my work is kind of like outreach in a way informing the public about what resources are available, creating guidance for local agencies in how to use climate change information and model outputs and also tracking and supporting implementation of big state regional management programs. Sustainable groundwater management requires a lot of technical assistance to locals, so just supporting those efforts

**A:** Do you have any specific areas you're looking at now? Or is it pretty general

**W:** Well my specific focus is on the larger system, so in California there are over 3000-4000 reservoirs. Of those, 15-20 percent make up 90 percent of the water supply. So you have many small reservoirs that are large enough to be regulated. But the biggest reservoirs represent the majority of the surface supply and all of those larger reservoirs are spread out from North to South and are all connected by this giant conveyance network and that network passes through one of the most sensitive ecosystems in California. Which used to be back before humans (Spanish and American) settlers came and took the land from the natives and started developing. It used to be an enormous estuary. A big conveyance network takes water from the north and takes it to the south. So my work is mainly focused in looking at that particular constraint to managing water supply in California along with the trade offs with those constraints like environmental requirements and reservoirs themselves. There's a bit of a conflict with how low you can keep a reservoir and how high you can keep it.

**A:** Are the reservoirs connected by a natural river

**W:** They are and they aren't, so as far as conveyance goes yes the natural stream source of the Sacramento is the natural weather but is used partially. It conveys water through it. We manage the flows through it and alter the natural hydraulics of the estuary. So yes it is natural but there are also constructed canals that connect different reservoirs in different parts. Built but 3 levels of governance.

**J:** What weather indicators do you look at that could impact the conservation or management of the area?

**W:** Weather extremes that were managed in such a way that they didn't become disasters. One was the main reservoir, Lake Orville, and in 2017 there was a successive change of atmospheric river events where California gets most of its water supply from. If met at the same time it poses a massive flood risk. These types of storms are warm compared to other storms so you get a lot of runoff. Orville was filling quickly and as it was filling up and they were releasing water the spillway failed and they shut it down and the reservoir filled even more and then another storm came. They realized we were going to have to activate the emergency spillway to allow the water to evacuate so it didn't over top the dam. So they activated it that hadn't ever been activated, essentially it is a berm on the side of the dam but below the berm it's just a hillside. They realized if we keep using it it's going to fail and have a disaster. They reactivated the original spillway until it started to fall apart and came really close to completely failing and becoming a flood disaster, so it was a big evacuation with hundreds of thousands of people. As far as my work goes it's a big agency but I'm not a part of the operation for emergencies but it impacted my work and the emphasis of work for analysis. The other was the drought in 2016 most significant on record. Because California has a large groundwater resource to draw on during these periods agriculture doesn't suffer. In any case, flood risk and droughts

are being tested by extreme events, and groundwater has buffered these impacts. But to get to a point where the resources are managed in a sustainable way, management will need to change or it will become a disaster in the future.

**J:** What weather indicators do you look at that could impact the conservation or management of an area?

**W:** It depends on the context, if you're monitoring the Sacramento delta, and what needs to happen to prevent necessary impacts, you're monitoring air temperature, all the flows and all the channels, you're monitoring salinity, how weather impacts flows in the delta and air temperature and how it combines. But if you're a dam operator you're monitoring forecasts of stream flow which are based on the condition of the upper watershed based on soil moisture, snow pack, snow level, and different flows and gauges in the upper watershed but you're also monitoring rain projected storm temperature and how does that relate to runoff to expect. Dam operators will use this information on a short term basis to govern how much water they will release from the reservoir. Or build up storage. It's very seasonal. But then on a long term scale thinking about the next year or how much water you will need to release for the summer you are monitoring forecasts for how much volume to expect over several months which will change how conservative operators will deal with reservoirs and how much water will be released. And then of course you have long term indicators which are in a hydro report which shows trends in temperature, precipitation, hydrologic year types, trends in snow level, all of which is affected by rising climate change. A high significance level in the past 30-40 levels. Precipitation is difficult to detect due to variability. It's affecting snow level and proportion of snow vs rain level.

## D. Community Surveys

To obtain the community interviews we worked with one of our sponsors, Rafael A. Rodriguez Santiago. We sent him the list of questions detailed below to ask community members or employees that visit La Plata Nature Refuge. We utilized the help of Rafael because he is bilingual and most of the people available only spoke Spanish. The responses to the questions below have been translated from Spanish to English by Rafael. The surveys helped us to gain an understanding of the local thoughts on the area and how they have been impacted from different events. The process helped us since we couldn't be in the area in person, however we were also limited in our surveys because of this. If we had been there in person the process of obtaining surveys would have been more natural and we might have several more.

Summary of responses to the community surveys.

<b>Effects experience from Hurricane Maria</b>	<ul style="list-style-type: none"> <li>● Loss of electricity             <ul style="list-style-type: none"> <li>○ Started using power plants</li> </ul> </li> <li>● Loss of running/drinking water</li> </ul>
<b>Uses for La Plata Refuge</b>	<ul style="list-style-type: none"> <li>● Recreational activities             <ul style="list-style-type: none"> <li>○ Fishing</li> <li>○ Exercising</li> <li>○ Hiking</li> <li>○ Kayaking</li> </ul> </li> <li>● A space to spend time with friends and family</li> <li>● A source for potable drinking water</li> </ul>
<b>Greatest concerns for La Plata Refuge</b>	<ul style="list-style-type: none"> <li>● Not given the attention it needs/deserves</li> <li>● Reservoir levels continuing to drop annually</li> <li>● Water restrictions</li> <li>● The recreational area closing due to natural disasters and slow clean up</li> </ul>
<b>Potential hazards for living area</b>	<ul style="list-style-type: none"> <li>● Earthquakes and aftershocks cracking and breaking the dam</li> <li>● Droughts occurring at a high rate             <ul style="list-style-type: none"> <li>○ Loss of water source</li> </ul> </li> <li>● Trash in the reservoir and river</li> </ul>
<b>Greatest change observed to La Plata Refuge</b>	<ul style="list-style-type: none"> <li>● The La Plata reservoir used to be a river and then was turned into a dam. This has changed the landscape of the refuge and surrounding river area</li> </ul>

Name (optional, if included you give us permission to list your name in the final research report)

Wilfred Maysonet  
 Elisa Santiago Cruz  
 Felix Figueroa Loarte

1. How old are you?
  - a. 58 years old
  - b. 57 years old
  - c. 64 years old
  
2. How long have you been living near the river? (if applicable)
  - a. 58 years
  - b. 50 years

- c. 44 years
3. **How long have you been going to/using the reservoir?**
- a. Since 1973
  - b. 40 years
  - c. 20 years
4. **How have you been affected by hurricane Maria?**
- a. I've been affected only by having electricity and water.
  - b. During the time of Hurricane Maria, it rained almost every day. We didn't have water nor electricity. For the water, we used drones, let them fill with rain water and use that water to wash our clothes, for bathrooms, for bathing, and washing the dishes. We put Clorox in the water so it would be clean water. For the electricity, we bought a power plant[generator] so it could provide electricity for the fridge.
  - c. Hurricane Maria affected my restaurant business a lot since I depended on the business. Right now business is still being affected because of the pandemic but I remember during that time I was struggling to get electricity so I depended on power plants. [generators]
5. **How do you consider yourself part of the community?**
- a. I identify as a public service at Wildlife Refuge La Plata Reservoir.
  - b. I give myself entirely to my family and friends.
  - c. Since I have a restaurant business, I think myself a public figure. I am also a contractor who I tend to meet many people.
6. **What do you use the La Plata river, refuge, and reservoir for?**
- a. Part of the job as a public service worker for Wildlife Refuge Embalse La Plata. Recreational and for use of potable water.
  - b. My family goes fishing a lot in La Plata Lake. We love to enjoy our family time together. La Plata reservoir supplies water to my house.
  - c. I use La Plata river, refuge, and Reservoir for recreational activities, fishing, and also for exercising.
7. **What are you most concerned about regarding the La Plata river, refuge and reservoir?**
- a. That they don't give the tendencies it deserves.
  - b. I am concerned that reservoir levels continue to drop more than previous years and they start restricting the water again.
  - c. The recreational area is out of use due to the unstable bridge. I wish they would open up as soon as possible. They must give the project necessary resources for it to be open.
8. **What major hazards or issues affect your area?**
- a. More droughts and more trash in Lago La Plata.
  - b. I'm worried that the Dam gets to crack because of the earthquakes and the aftershocks.
  - c. There are no major hazards or issues that affect my area.
9. **How do you feel this will change with climate change?**
- a. Drought seasons are going to get worse.
  - b. It could have a major impact on our water resource if we get to lose the dam; also it can be a disaster for many people in Toa Alta and the metropolitan area of Puerto Rico.
10. **How important is planning for the future of the town and its people to you?**
- a. It's important to plan the future in helping to serve the people of Puerto Rico.
  - b. I want more union in Puerto Rico on finding more peace. No more violence. I want to take care of my family for the good. So the main thing I want is union for all of Puerto Rico.
  - c. Is important for the youth because it is rising. We need everything to be more organized since it's growing more. Unfortunately, everything feels like it is stagnating in Puerto Rico from everything that has happened.

**11. What changes have you seen in the river in the time you have been living here?**

- a. That it was not a reservoir as such it was a river. In the river there were several puddles, and it was enjoyed more. It was used more for bathing and fishing. The puddles were called Charco Frio and Los Hoyos. When the reservoir was being created you could feel the dynamites explode in the area. Before, more eel, Guabina, olive and shrimp were fished.
- b. The changes that I have seen are the levels of the water go down more in dry seasons. Before it was a reservoir it was a river. Now they have built a dam and is now a lake. Unfortunately, they are more people that have drown in the lake that were when it was a river.
- c. I used to go horseback riding beside the river and also swim against the current of the river. I saw how the reservoir was built. In the process of how it was being built I saw how the water began to accumulate. I used to work on the dairy farm before this Project. My father was a Butler in charge of the farm itself. Around that time, it was one of the most modern dairy farms from that time which is why the project's soil is very rich in nutrients. I miss swimming in the river. It was different times now you can't go swimming in the lake.

## E. News sources

These news sources were used to search for local images in Puerto Rico after significant events. The goal was to find more images along La Plata Reservoir or River. Searches were done by typing in “drought”, “earthquake” or “hurricane” to find images from those events. The images were used to supplement the community surveys because we didn’t receive many pictures from them. The news sources we searched in were:

1. El Nuevo Día - <https://www.elnuevodia.com/>
2. The San Juan Daily Star - <https://www.sanjuandailystar.com/>
3. WAPA.tv - <https://www.wapa.tv/>
4. El Vocero - <https://www.elvocero.com/>



## F. Images from Sponsor

To supplement the images from news sources we also received more local images from our sponsor. These are images mainly of La Plata Reservoir during times of flooding or drought. We also used these images to confirm what we were seeing in satellite imagery. They also gave us a more direct perspective of the reservoir during these events. Find more analyses of the images in the Photo Results section of the final report.

### Flooding

The images below show the banks of La Plata Reservoir when the area is flooded. There is no major change however, the water level comes up to the pavilion. In normal conditions, these pavilions would be further away from the water line.



## Drought

The images below show La Plata Reservoir in 2014-2016 during intense drought in Puerto Rico. In the images you can see that the water level is much below normal, due to the exposed soils.









The images below and on the right were taken from a plane by the National Guard on August 5, 2014. The images provide a quality and closeness that we could not achieve with satellite imagery from Google Earth Pro. The peninsula depicted in the images is usually underwater. The white squares are the docks shown in the image on the left with people on them. However, in the National Guard images the docks are sitting on the ground because the water level has dropped so low.



## G. Satellite Imagery Assessment

A brief assessment of satellite imagery sources is shown in the Table below. Google Earth Pro was selected based on ease of use and ability to save images. A lack of images in Google Earth has caused some gaps in our results which could be filled by finding images from one of the other sources listed in the table.

Satellite Image Databases	Pros	Cons
Google Earth Pro (used for this project) ( <a href="https://www.google.com/earth/versions/">https://www.google.com/earth/versions/</a> )	<ul style="list-style-type: none"> <li>• Easy to use</li> <li>• Can save images</li> <li>• Create different layers or markings on images</li> </ul>	<ul style="list-style-type: none"> <li>• Missing certain dates in early 2000s</li> <li>• Quality of images when zoomed in is lacking</li> </ul>
Landsat ( <a href="https://landsat.gsfc.nasa.gov/data/where-get-data">https://landsat.gsfc.nasa.gov/data/where-get-data</a> )	<ul style="list-style-type: none"> <li>• Appears to have lots of data</li> </ul>	<ul style="list-style-type: none"> <li>• Unclear on how to obtain images</li> <li>• Images in web browser are blurry if zoomed in to particular location</li> </ul>
USGS Earth Explorer ( <a href="https://earthexplorer.usgs.gov">https://earthexplorer.usgs.gov</a> )	<ul style="list-style-type: none"> <li>• Cleaner images when zoomed in</li> <li>• Includes land cover, vegetation monitoring,, Landsat, and National Aerial Photography Program data</li> </ul>	<ul style="list-style-type: none"> <li>• Maps are not for purchase or download</li> <li>• So many datasets from different sources it is unclear what to use what for or what source is best</li> <li>• Unclear how to actually gain images over time</li> </ul>
NASA Worldview ( <a href="https://worldview.earthdata.nasa.gov/">https://worldview.earthdata.nasa.gov/</a> )	<ul style="list-style-type: none"> <li>• Lots of data layers</li> </ul>	<ul style="list-style-type: none"> <li>• Image is too blurry when zoomed in</li> <li>• Sometimes images don't show up over Puerto Rico or other locations</li> </ul>
NLCD ( <a href="https://www.mrlc.gov/viewer/">https://www.mrlc.gov/viewer/</a> )	<ul style="list-style-type: none"> <li>• Lots of land cover data</li> <li>• Clear way to download</li> </ul>	<ul style="list-style-type: none"> <li>• Sometimes unable to open files on certain computers</li> </ul>
ABI Bands ( <a href="https://www.goes-r.gov/">https://www.goes-r.gov/</a> )	<ul style="list-style-type: none"> <li>• Used for extreme weather events</li> </ul>	<ul style="list-style-type: none"> <li>• Unclear of where to actually get images for use for particular areas</li> </ul>

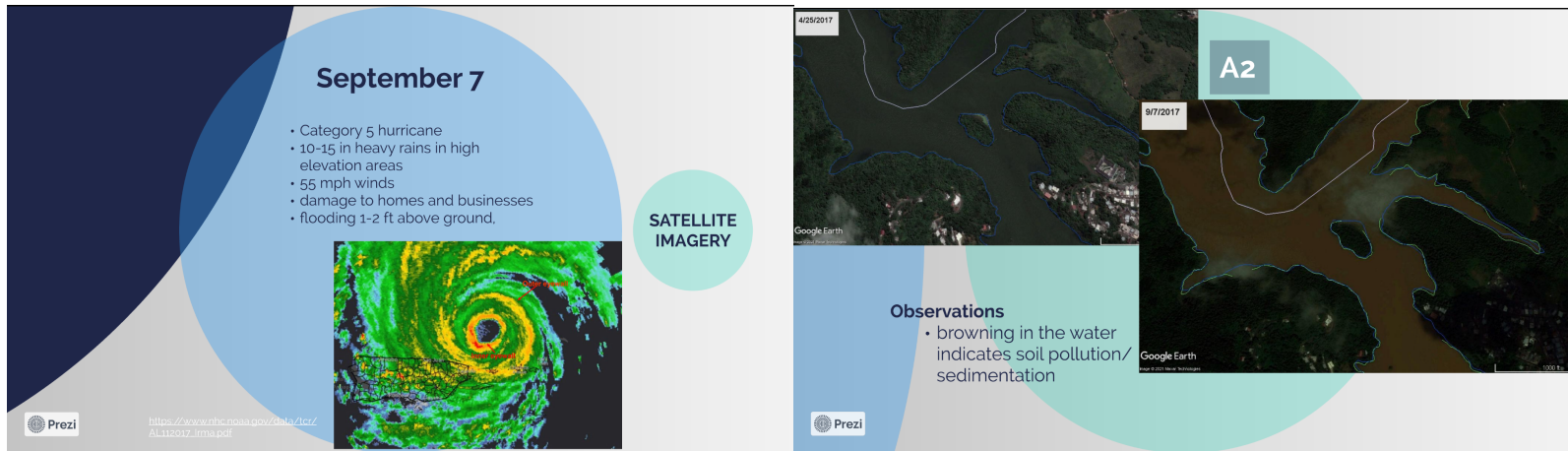
# I. Deliverables

## Prezi

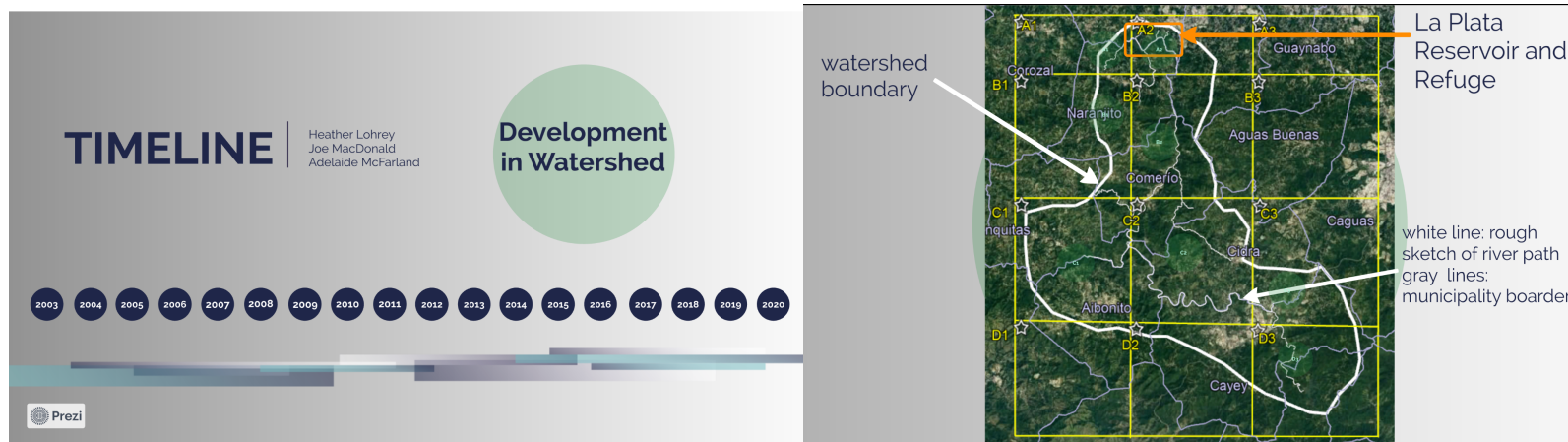
Prezi was used to create an interactive experience for users that includes both our event timeline and combined satellite imagery. This timeline can be built upon within the coming years with new satellite imagery or any imagery of change that our team may have not discovered. The link to the Prezi can be found here (<https://prezi.com/view/XnSSHt90PQRDbxTIM1Bz/>). Below are some example images of the information in the Prezi.



Overall timeline image (left). Image view when you click on a year, shows watershed from that year and the events that occurred (right).

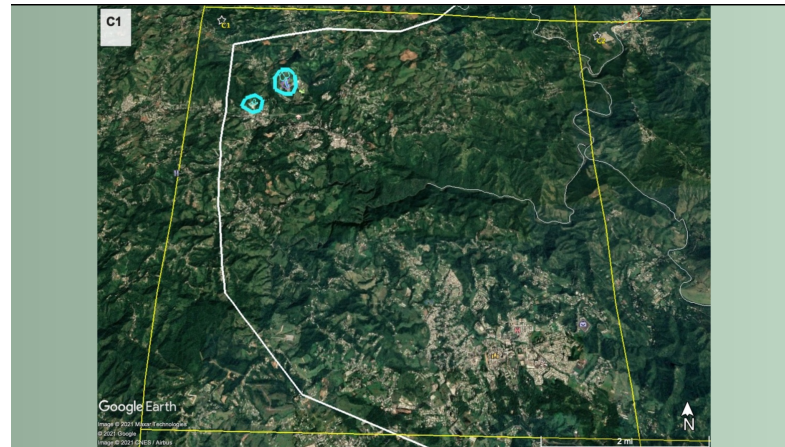


Examples of the impacts and satellite imagery when you click on a specific event in a year. Includes observations and location of the image.

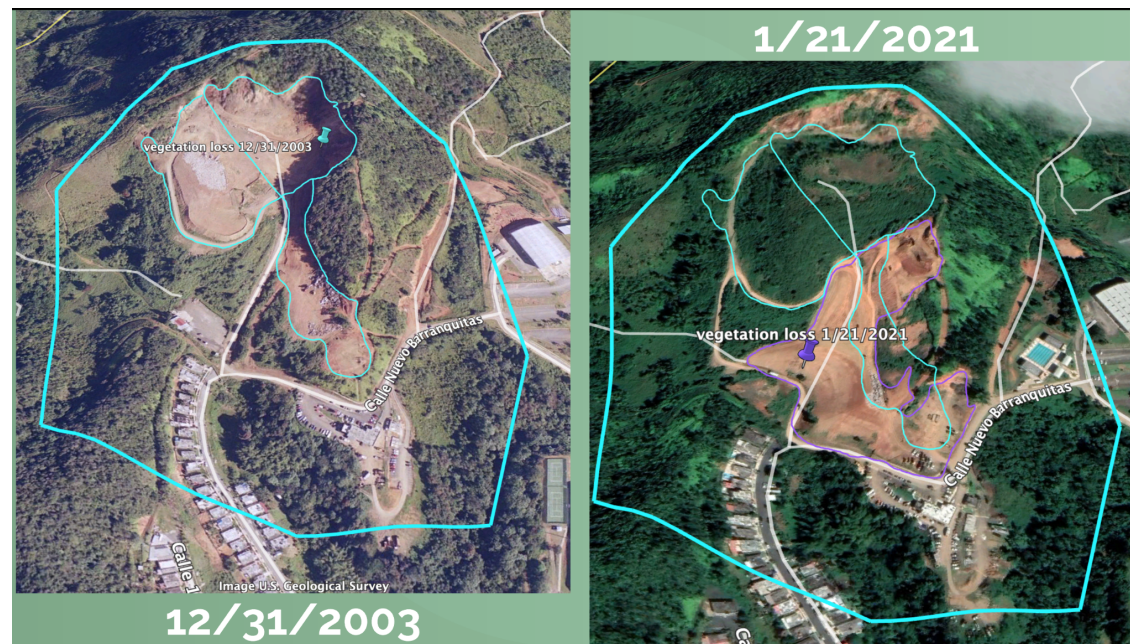


Clicking on "Development in Watershed", will take you to the map of the entire watershed where you can then click on a specific circle in a section of the map.





After the section of the watershed is selected, you can click on an outlined development in the section.



The details of the development including a before and after comparison will be displayed.



## Google Earth File

In order to pass on our research to a future team as well as the sponsor, we have attached our Google Earth File at <https://digital.wpi.edu/>. You can find it by using the browser to locate Puerto Rico projects and then searching with the project title “La Plata Nature Refuge: Assessing Land Change”. This file details paths, polygons, pins, and boundary outlines that we used to observe changes to the land throughout our project. To understand how to use the file and add more information see Google Earth User Guide below.

## Google Earth User Guide

Because we are passing our Google Earth file on to the sponsor and potentially a future team, we made a tutorial on how we used each component of the platform. The tutorial consisted of a video and powerpoint slide. The video was made with voice over and walks through the steps of using Google Earth from downloading it onto a computer to drawing paths and polygons on the images. The presentation we made synthesizes the information in the video in one place. It is intended to be used after watching the video when a reference to one task is needed. The video and presentation can be found at <https://digital.wpi.edu/> by using the browser to locate Puerto Rico projects and then searching with the project title “La Plata Nature Refuge: Assessing Land Change”.

## ArcGIS Prototype

As a part of our recommendation we suggest a future team build from our ArcGIS prototype linked here (<https://arcg.is/CK4P00>). The map includes feature layers of waterways, flood zones, land cover, and land use. Features in waterways and land use are key to understanding the changes occurring in the La Plata region. Additional layers can be added as described in Recommendations. The map itself has been made public but some layers may require an account to view. An account can be obtained for ArcGIS online from your institution or company as needed. Tutorials and lessons on how to use ArcGIS online can be found here (<https://learn.arcgis.com/en/gallery/>). Images of the prototype can be seen below.


## Prototype for Future Project Team

Overview Usage Settings

 Edit thumbnail



 Add to Favorites

This map is meant to serve as a prototype of layers possible for future land change analysis at La Plata Nature Refuge. This map serves as a starting point for predictive modeling with ArcGIS Model Builder to predict future changes to the land. 

 Web Map by [hnlohrey\\_WPI](#)

Created: Apr 15, 2021 Updated: May 5, 2021 View Count: 25

 Edit

### Description

[Add an in-depth description of the item.](#)

### Layers


[HOTOSM Puerto Rico Waterways - Lines \(OpenStreetMap Export\)](#)


[HOTOSM Puerto Rico Waterways - Polygons \(OpenStreetMap Export\)](#)

[Puerto Rico Flood Zone 1 PCT](#)

[USA NLCD Land Cover](#)


[USA NLCD Tree Canopy Cover](#)

[Open in Map Viewer Classic](#) 

[Open in ArcGIS Desktop](#) 

[Create Presentation](#)


[Open in Field Maps](#)

[Create Web App](#) 

[Share](#)

### Item Information Learn more

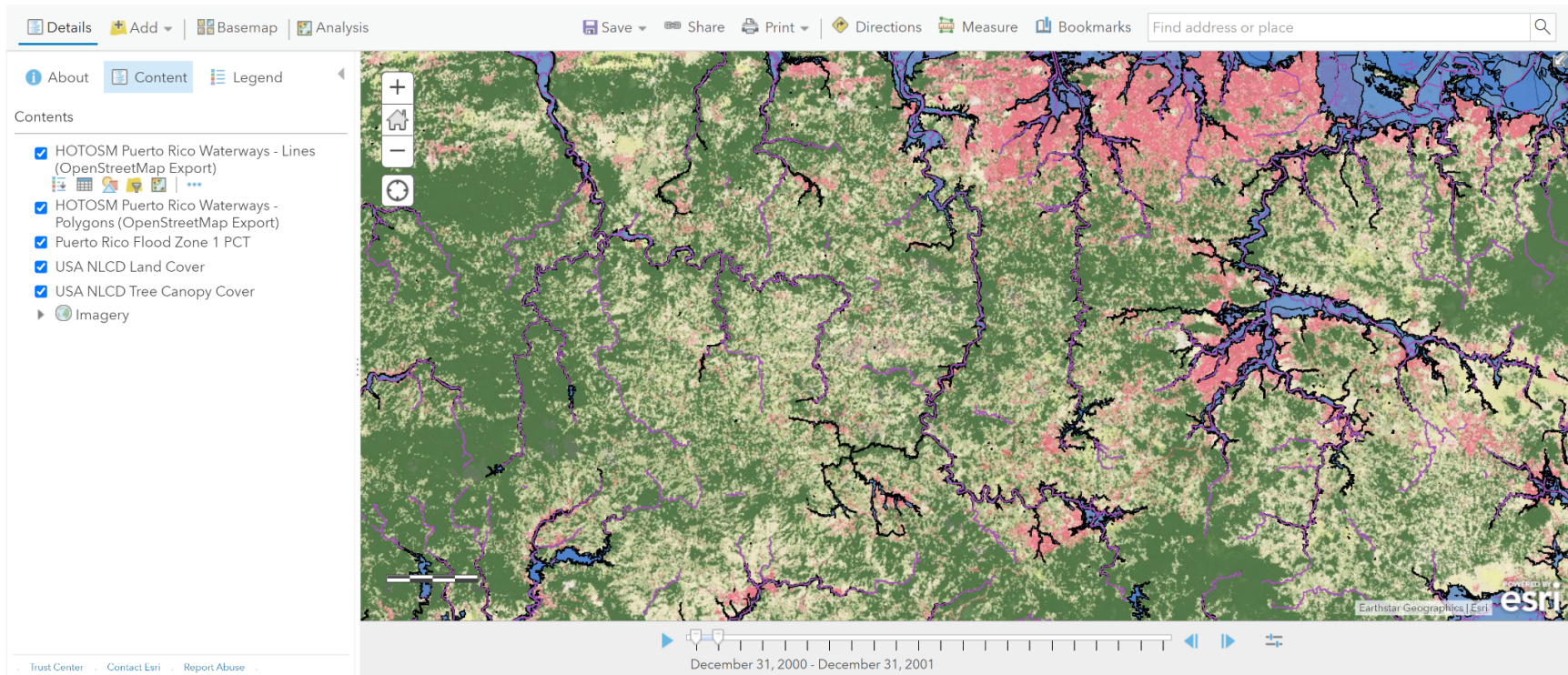
Progress bar from Low to High

 Top Improvement: [Add a description](#)

### Details

Size: 29 KB

This shows the detailed content for the ArcGIS prototype file. The name for the map is at the top in the blue bar.



This shows a view of the prototype when you open the map in viewer. In this view the map can be edited or added to.